# Monetary policy strategies: abandonment, adoption, and performance

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# Monetary Policy Strategies: Abandonment, Adoption, and Performance

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by

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Anna Samarina

# Contents

*Chapter 1*

# Introduction

## 1.1 Background and motivation

The choice of a monetary policy strategy has been an important topic in economic research and central banks' policy making. According to Houben (1999) and Walsh (2004), a monetary policy strategy is a complex framework, which identifies objectives, an information structure and targets used by central banks to achieve the ultimate goals of monetary policy. The strategy guides a central bank in selecting and using monetary policy instruments in order to achieve price stability and other macroeconomic objectives.

Countries choose different monetary policy strategies depending on their characteristics and pursued policy objectives. Mishkin (1999) and Stone and Bhundia (2004) distinguish five main types of monetary policy strategies: three strategies with one explicit target, a strategy with multiple targets, and a strategy without an explicit nominal target. A country can adopt only one type of monetary policy strategy at a time.

Monetary strategies with one explicit target include inflation targeting, monetary targeting and exchange rate targeting.[1] Inflation targeting requires

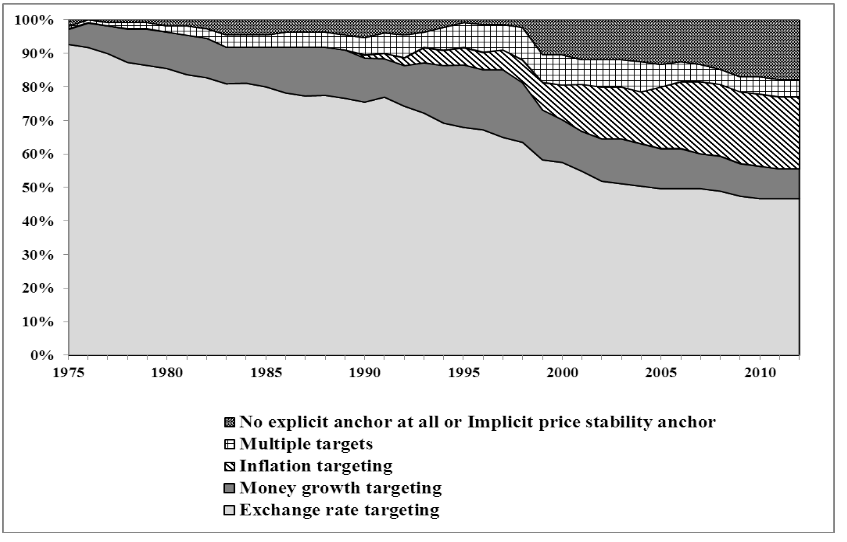
[1] The literature distinguishes also nominal income targeting and price-level targeting. The first one remains a theoretical concept as it has not been tried in practice (Mishkin, 1999). While some studies (Bernanke et al., 1999; Svensson, 1999) claim that price-level targeting was applied in Sweden in the 1930s, others (Rathke et al., 2011) argue that the Riksbank rejected the idea to target the price level. This strategy has not been used by any other country.

a public announcement by central banks of numerical targets for inflation and a strong commitment to these targets. Monetary targeting involves setting medium-term targets for the growth rates of monetary aggregates. Exchange rate targeting is based on fixing the exchange rate of the domestic currency to that of a large, low-inflation country, and applying monetary policy instruments to keep the exchange rate at a fixed level or to keep its movements within a fixed band. Finally, some central banks conduct monetary policy with more than one explicit target (e.g., the multiple indicators approach in India (Patra and Kapur, 2012)) or without an explicit anchor (e.g., the 'two perspectives approach' in Japan, the two-pillar framework of the ECB, and the eclectic strategy of the Federal Reserve System (Cuaresma and Gnan, 2008)).

In recent decades, many countries changed their monetary policy strategies. Figure 1.1 shows the evolution of monetary strategies for 135 countries over the 1975–2012 period. Several important trends can be discerned. First, after the collapse of the Bretton Woods system many countries abandoned fixed exchange rates in favor of floating exchange rate regimes. This led to a decline in the share of countries having a fixed exchange rate regime from over 90% in 1975 to about 50% in 2012 (mostly emerging and developing countries). Second, the popularity of monetary targeting dropped over time; it disappeared completely in advanced countries by the late 1990s. Still, several emerging and developing countries are implementing this strategy at present. Third, an increasing number of countries have adopted inflation targeting in the last two decades. Finally, many countries switched to monetary strategies with no explicit anchor or with an implicit price stability anchor. Such strategies may be attractive because they allow for more flexibility and imply less commitment in monetary policy conduct.

Central banks can choose from a wide variety of monetary policy strategies. Given that countries do not maintain one strategy at all times but switch from one type of monetary strategy to another, one may wonder what makes countries prefer one particular strategy over the other, i.e. what drives their choice of a monetary policy strategy.

Figure 1.1. **Evolution of monetary policy strategies, 1975–2012**




Source: Own classification based on Fatás et al. (2004), Stone and Bhundia (2004), Ilzetzki et al. (2011), IMF Annual Reports on Exchange Arrangements and Exchange Restrictions (AREAER), and central banks' publications.

The academic literature provides different perspectives on the choice of a monetary strategy. Many studies recommend inflation targeting in advanced and emerging countries (Mishkin and Schmidt-Hebbel, 2007; Roger, 2009). Others (Fatás et al., 2004) suggest exchange rate targeting for developing countries. Monetary targeting, which has been commonly criticized, was quite successful in countries such as Germany and Switzerland and is still applied in several developing countries. Thus, there does not seem to be one monetary strategy, applicable at all times. Countries select a strategy which they believe to be the best option under given circumstances. Therefore, to understand why countries adopt or abandon a particular monetary strategy, it is important to examine the potential factors driving this decision.

According to Houben (1999), Truman (2003), and Fatás et al. (2004), the choice of an appropriate monetary policy strategy depends on the nature of shocks that affect the economy, its structural, fiscal, monetary, and financial characteristics, exchange rate arrangements as well as its institutional framework. In addition, prioritization of macroeconomic objectives and the political environment may play a role.

Only a few empirical studies have examined the factors leading to adoption or abandonment of a particular strategy. The only exception is exchange rate targeting, which has been analyzed extensively in the literature. As monetary targeting and inflation targeting are, next to exchange rate targeting, the two most important monetary policy strategies practiced by modern central banks, this thesis concentrates on them.

Previous research on monetary targeting (see Chapter 2) mainly explores the conditions required to adopt this strategy. However, there is no empirical study so far that examines why countries abandon monetary targeting. Although at present no advanced country uses monetary targeting in its pure form, the research on monetary targeting abandonment remains important for those emerging and developing countries that apply this strategy but may decide to give it up in the near future.

In recent research, special attention has been given to the analysis of the performance of inflation targeting countries as well as the factors that led countries to adopt this strategy (see Chapters 3 and 6 for literature reviews). Although there are several studies on this topic, they did not reach a consensus on what factors influence inflation targeting adoption and whether this strategy indeed helps to reduce inflation.

The existing literature on the adoption of inflation targeting has several limitations. First, previous studies examine general macroeconomic indicators only and ignore financial system characteristics as possible drivers of inflation targeting adoption. The financial aspect is significant for this analysis, since the financial system plays an important intermediary role between the actions of a central bank and their impact on the real economy. Thus, financial system characteristics could also influence the choice of monetary policy strategies.

Second, previous studies use an incorrect methodological approach by retaining the observations before and after the adoption of inflation targeting in the analyzed sample. Thereby they do not differentiate between the factors of inflation targeting adoption and the factors driving its continuation; consequently, they simultaneously estimate both. This may lead to biased results due to endogeneity problems.

Finally, the methodology used in existing studies applies ordinary binary response models and ignores the existence of spatial interdependence between countries in a monetary strategy choice. A spatial approach in monetary policy has been used mainly for the analysis of interregional dependence (e.g., Di Giacinto, 2003). However, few studies analyze spatial dependence between countries, especially in the context of the choice of a monetary strategy. Applying a spatial approach to the analysis of inflation targeting can explain how the adoption of inflation targeting by one country is affected by the monetary strategy choice of other countries. To the best of our knowledge, only Mukherjee and Singer (2008) examine spatial interactions between inflation targeting countries; however, these authors do not take into account that countries that already adopted inflation targeting may have a different impact than those that have not yet adopted it. Disentangling these two effects is relevant when countries adopt a strategy at different moments in time.

This thesis contributes to the literature by extending the analysis of monetary policy strategies and dealing with the above limitations in the following ways. First, we examine two monetary policy strategies, namely monetary targeting and inflation targeting. Second, we include a wide range of macroeconomic, fiscal, external, financial, and institutional factors that may influence the decision to abandon monetary targeting or to adopt inflation targeting. Third, we modify the methodological approach to inflation targeting adoption by leaving out the observations after adoption. This is an innovative approach that has not been used before in this line of research. Fourth, we use spatial econometrics techniques to examine spatial interactions between countries in inflation targeting adoption. The methodological innovation is in constructing a spatial probit model with two spatial variables that takes into account that countries adopt inflation targeting at different moments in time. The spatial analysis provides insights into understanding the interdependence between countries and coordination of central banks in the context of a monetary strategy choice. Finally, the thesis adds to the academic debate on inflation targeting by conducting a comprehensive robustness analysis of the effects of inflation targeting on inflation.

This research brings new insights into understanding the relations between monetary policy, the financial system, and the real economy. It has an important practical application for central banks' decision making and the construction of an appropriate monetary strategy framework.

## 1.2 Research questions

The overarching research question that motivates the research conducted in this thesis is: what drives countries' choice to adopt/abandon a particular monetary policy strategy? To answer this general question, we specifically examine the following four research questions:

1. Do financial system changes affect the decision to abandon money growth targeting?

2. Which factors lead to inflation targeting adoption?

3. How do spatial interactions between countries influence the decision to adopt inflation targeting?

4. Does inflation targeting have an impact on inflation and does this impact differ across countries?

Answering these research questions will increase our knowledge of the factors influencing the choice of both monetary strategies. Furthermore, the analysis of spatial interdependence between countries is of great importance, because spatial econometrics has not been broadly applied to the field of monetary policy. Additionally, to provide a reliable answer to the last research question, we conduct the analysis with different methodologies, country samples, periods, and adoption dates of inflation targeting; such a comparative analysis has not been done before.

## 1.3 Outline of the thesis

The rest of the thesis is structured as follows. Chapter 2 analyzes the factors of monetary targeting abandonment. Chapters 3–6 focus on inflation targeting. Whereas Chapters 3–5 investigate the factors leading to inflation targeting adoption, Chapter 6 examines whether this strategy has an impact on inflation. Chapter 7 concludes.

We start with monetary targeting as it was the first monetary policy strategy adopted by countries after the collapse of the fixed exchange rates system in the 1970s. Chapter 2 focuses on the first research question and examines how reforms and characteristics of the financial system affect the likelihood of countries to abandon monetary targeting. Apart from financial system characteristics, we include macroeconomic, fiscal, external, and institutional factors potentially associated with countries' decisions to give up monetary targeting. Panel logit models are estimated for a sample of 35 monetary targeting countries over the 1975–2009 period. We find that changes in the financial system, such as financial liberalization, deregulation, and development as well as dollarization, significantly increase the probability to abandon monetary targeting. Additionally, more developed countries with lower inflation and larger fiscal deficits are more likely to give up this strategy. An important outcome is that the financial determinants of abandoning monetary targeting differ between advanced and emerging and developing countries.

Chapter 3 answers the second research question by examining which economic, fiscal, external, financial, and institutional characteristics of countries affect the likelihood that they adopt inflation targeting as their monetary policy strategy. We apply panel probit models for a sample of 60 countries and two subsamples consisting of OECD and non-OECD countries over the 1985–2008 period. In contrast to previous studies, which include the pre- and post-adoption periods in the analysis, we focus exclusively on the factors leading to inflation targeting adoption and leave observations after adoption out of analysis. The results suggest that past macroeconomic performance of a country, its fiscal discipline, exchange rate arrangements, as well as the structure and development of its financial system significantly affect the likelihood to adopt inflation targeting. However, the factors leading to inflation targeting adoption differ significantly (in a statistical sense) between OECD and non-OECD countries and between soft and full-fledged inflation targeters.

Chapter 4 examines to what extent the analysis of inflation targeting adoption is affected by the choice of the analyzed period, i.e., by either keeping or discarding observations for the post-adoption period. The first approach may cause endogeneity and asymmetry problems. Once inflation targeting is adopted, country characteristics and institutions adjust in a way that makes them compatible with the inflation targeting framework. This reinforces the decision to continue with inflation targeting. Consequently, the impact of the factors after adoption is altered by the implementation of inflation targeting; hence, these factors cannot be treated as exogenous. We test whether country characteristics influence the decision to apply inflation targeting differently before and after its adoption, using panel probit models for the dataset of Chapter 3. The findings suggest that the factors leading to inflation targeting adoption differ significantly from those leading to its continuation. Thus, including the post-adoption period when estimating the factors driving inflation targeting adoption leads to biased results.

Chapter 5 focuses on the role of spatial interactions between countries in inflation targeting adoption. We analyze whether a country is more likely to adopt inflation targeting if (culturally or institutionally proximate) neighboring countries have adopted the same strategy. We take into account that: (i) countries adopt inflation targeting at different moments in time; (ii) neighboring countries that did not adopt inflation targeting yet may have a different impact than countries that already adopted it. We develop a spatial probit model with two spatially lagged variables, one for countries that did not adopt inflation targeting yet at the start of the period and one for countries that already adopted. The first spatial term is specified as unobserved choices, while the second one as actual outcomes. We use several spatial weights matrix specifications to control for geographic, cultural and institutional proximity. The dataset is based on the one used in Chapter 3. Our results are sensitive to the choice of a spatial weights matrix. We find that for the common language weights matrix the interaction effects with countries that adopt inflation targeting in the current period are insignificant, while the countries that already adopted inflation targeting have a significant negative effect on others to adopt. Additionally, for a spatial weights matrix based on common legal origins, countries that adopt inflation targeting in the current period have a significant positive impact on the decision of others to adopt. For the ten-nearest neighbors' matrix both spatial interaction effects are insignificant.

Chapter 6 focuses on the final research question. While the previous three chapters discuss what factors drive inflation targeting adoption, this chapter explores whether this strategy is effective in reducing inflation. This study performs a comprehensive sensitivity analysis of the effects of inflation targeting on inflation and examines to what extent the outcomes are influenced by the selection of country samples, adoption dates, time periods, and methodological approaches. Two estimation techniques are applied — difference-in-differences and propensity score matching — for a sample of 25 advanced and 59 emerging and developing countries over the 1985–2011 period. Our findings suggest that distinguishing countries by economic development is crucial, as there is no effect of inflation targeting on inflation for advanced economies, whereas inflation targeting contributes significantly to decreasing inflation in emerging and developing countries.

The final chapter summarizes the main findings, discusses their policy implications, and mentions directions for future research.

*Chapter 2*

# Monetary targeting and financial system characteristics*

## 2.1 Introduction

The collapse of the Bretton Woods system in the mid-1970s forced countries to search for an alternative nominal anchor for monetary policy under the floating exchange rate regime. As a solution, the Monetary Targeting (hereafter, MT) framework was created. Inspired by the quantitative theory of money propagated by monetarists, central banks of several advanced countries started using monetary aggregates as intermediate targets in their monetary policy conduct (Argy et al., 1990; Mishkin, 2006; Woodford, 2008). Central banks believed that targeting money growth could anchor inflation expectations and ensure price stability.

According to Argy et al. (1990) and Mishkin and Savastano (2001), MT involves the public announcement of medium-term targets for the growth rates of some monetary aggregate(s), the reliance of monetary policy conduct on information conveyed by this (these) aggregate(s), and strong accountability of a central bank to reach monetary targets. The success of MT relies on strong assumptions: stability of the money demand function and

* This chapter is based upon Samarina (2012). We thank Alex Cukierman, Maria Grydaki, Roman Horváth, Michael Koetter, and the participants of the WEAI Conference 2012, San Francisco and the EPCS Meeting 2013, Zürich, for helpful comments and suggestions.

the existence of a strong and reliable relationship between the targeted monetary aggregates and goal variables — inflation and/or nominal income (Mishkin and Estrella, 1997; Mishkin, 2006).

Back in the 1970s, MT was considered a good alternative to exchange rate pegs. It was relatively easy to monitor and communicate this strategy to the markets. Moreover, monetary targets could be understood by the general public (Mishkin and Savastano, 2001; Mishkin, 2006). However, the initial enthusiasm about MT turned into a disappointment. The money demand function was unstable in most MT countries and central banks were unsuccessful in controlling the money stock. Additionally, MT central banks suffered a credibility loss as they frequently missed money growth targets. Exceptions were Germany and Switzerland, where MT was effective in controlling inflation thanks to the active and clear communication of the strategy to the public (Mishkin, 1999).[1] The sustained costs of MT implementation, including low institutional credibility and failure to achieve price stability, forced countries to quit this strategy.[2] Until the late 1990s, all advanced countries abandoned MT. Meanwhile, many emerging and developing economies adopted MT in the 1980s and 1990s, and some of them are still pursuing it at present (Roger, 2009).

This chapter investigates the causes and conditions that led countries to MT abandonment. Mainly, we are interested in the impact of financial system characteristics and reforms on the probability to give up MT.

Although advanced countries do not pursue MT anymore, this research is relevant for emerging and developing countries which are still implementing MT, but may decide in the near future to give it up. It could be important for policy-makers in these countries to identify and monitor the factors that may lead to the ineffectiveness and abandonment of MT.

While the instability of money demand function is frequently mentioned in the literature as a major cause of MT breakdown (Mishkin, 1999; Wood-

[1] Some studies argue that German monetary policy during 1974–1998 was closer to inflation targeting than MT, as the Bundesbank announced inflation targets and used inflation forecasts in its monetary policy decision-making (Bernanke and Mihov, 1997; Mishkin, 1999).

[2] McCallum (1985) provides an elaborate review of the major criticisms and costs of MT.

ford, 2008), some macroeconomic, financial, and institutional characteristics of countries created unfavorable conditions for the implementation of MT and, consequently, increased the probability of its abandonment. In particular, reforms and changes in financial systems brought more diversification, deregulation, and development of financial products and services. This led to intensive and unrestricted flows of capital and money within the economy. As a result of these changes, it became difficult for central banks to control domestic credit and broad money supply. The increase in money supply can lead to higher uncertainty, which destabilizes money demand. Under these circumstances, central banks frequently missed money growth targets and eventually abandoned MT.

While there is an extensive literature that analyzes prerequisites of MT adoption, evidence on the causes of its abandonment is scarce. To the best of our knowledge, only Calderón and Schmidt-Hebbel (2008) apply binary-choice models to estimate the determinants of MT choice. However, there is so far no study that empirically analyzes the causes of MT abandonment and the role of financial system characteristics and reforms in this respect.

This chapter adds to the literature by empirically examining several characteristics of financial systems that could contribute to MT abandonment. We also include macroeconomic, fiscal, and institutional control variables potentially associated with countries' decisions to leave MT. Panel logit models are applied on a sample of 35 MT countries over the period 1975–2009.

We find that financial liberalization, deregulation, and development as well as dollarization significantly increase the likelihood to abandon MT. Additionally, more developed countries with lower inflation and larger fiscal deficits are more likely to switch from MT to an alternative strategy. However, the financial determinants to abandon MT differ between advanced and emerging and developing countries.

The rest of the chapter is structured as follows. Section 2.2 formulates the hypotheses based on theoretical literature. Sections 2.3 and 2.4 describe the methodology and the data. Sections 2.5 and 2.6 provide the main results and sensitivity analysis, respectively. Section 2.7 concludes.

## 2.2 The role of the financial system to abandon MT

Some studies argue that financial system changes, such as liberalization, deregulation, development, and dollarization destabilize money demand (McCallum, 1985; Argy et al., 1990; Issing, 1997; Houben, 1999; Roger, 2009). This means that money demand becomes less predictable and the linkages between monetary aggregates and macroeconomic variables (inflation and aggregate demand) weaken. Consequently, controlling the money stock becomes infeasible and money growth targets are missed. This forces central banks to suspend MT. Goldfeld and Sichel (1990, p. 300) emphasize the relevance of money demand for monetary policy and point out that "a stable demand function for money has long been perceived as a prerequisite for the use of monetary aggregates in the conduct of policy".

Following Goldfeld and Sichel (1990) and Ball (2001), the conventional money demand function has the form:

$$\log \frac{M_t}{P_t} = \alpha_0 + \alpha_1 \log Y_t + \alpha_2 \log R_t + \varepsilon_t, \tag{2.1}$$

where $M_t$, $P_t$, $Y_t$, and $R_t$ are the money stock, the aggregate price level, the real output, and the nominal interest rate, respectively; $\varepsilon_t$ represents money demand shocks.

According to Judd and Scadding (1982), money demand is stable when three conditions are satisfied. First, there is a statistically significant relation between money demand and its determinants, and these determinants can correctly predict money demand. Second, money demand cannot depend on too many variables, as that reduces its predictability. Third, the determinants of money demand should be linked to the real economy. As Judd and Scadding (1982, p. 993) conclude, "a stable demand function for money means that the quantity of money is predictably related to a small set of key variables linking money to the real sector of the economy". Since it is difficult to include money demand stability in the model due to the lack of a suitable measure, we cannot directly analyze its effect on the probability of MT abandonment. Instead, we examine financial system changes and characteristics that may cause money demand instability, and, consequently, indirectly contribute to the exit of MT.

Based on previous studies, we derive five hypotheses linking financial determinants with the probability to abandon MT.

### Financial (capital account) liberalization

According to Issing (1997) and Houben (1999), liberalization of external capital and money movements leads to the instability of the relationship between money supply and macroeconomic variables (inflation and/or nominal income). This makes the conduct of monetary policy based on targeting money growth more difficult.

By definition, capital account liberalization is a government's decision to allow capital to flow freely in (and out of) the country (Henry, 2007). It increases financial openness of the economy and leads to higher currency exposure. Under such conditions, achieving price stability through the control of monetary aggregates becomes infeasible. Moreover, the subsequent changes in financial and monetary conditions, including shifts in the capital assets demand and uncontrolled growth of the money stock increase the risk of missing money growth targets. In this situation, central banks abandon MT as this strategy cannot reach its objectives. Thus, our first hypothesis is:

Hypothesis 1: *Financial liberalization increases the probability to abandon MT.*

Turning to practice, Germany completed liberalization of its cross-border capital flows before the Bundesbank decided to adopt MT, which might explain why monetary conditions were rather stable in this country during the MT period (Issing, 1997). In contrast, other countries removed capital controls after they adopted MT. This caused radical changes in the financial system and money growth dynamics, leading to the ineffectiveness of MT.

### *Policy trilemma*: exchange rate regime and capital mobility

According to the *policy trilemma* hypothesis for open economies, a country can reach at the same time only two out of three policy objectives — monetary policy autonomy, capital mobility, and exchange rate stability (Obstfeld et al., 2005). Thus, conditional on the level of capital mobility (capital account liberalization), the choice of an exchange rate regime may have a different impact on the probability of MT abandonment.

If a country allows free movements of capital, it cannot simultaneously pursue an independent monetary policy and achieve exchange rate stability. With no capital restrictions in place and volatile exchange rates, countries often experience the 'fear of floating' (Calvo and Reinhart, 2000). To reduce exchange rate volatility, they limit exchange rate movements of their domestic currencies. Once a central bank focuses on pegging exchange rates, controlling the money stock becomes impossible due to the conflict between the objectives of exchange rate and price stability (Houben, 1999; Mishkin and Savastano, 2001). Thus, countries with fixed exchange rates will be more likely to abandon MT, conditional on high capital mobility.

However, if there is limited capital mobility, a central bank can retain policy autonomy and have a fixed exchange rate regime (Obstfeld et al., 2005). Hence, countries with fixed exchange rates can still practice independent monetary policy based on money growth targets. Our second, conditional, hypothesis is:

Hypothesis 2: *Countries with fixed exchange rate regimes are less (more) likely to abandon MT when they have limited (full) capital mobility.*

### Financial deregulation

Financial deregulation is the process of removing government restrictions, controls and regulations of the financial system (Gropp et al., 2007; Abiad et al., 2008). While financial liberalization is mainly associated with unrestricted external capital flows, domestic financial deregulation covers a broad range of financial reforms, such as removing credit, interest rate, and securities' markets controls, eliminating entry barriers into the financial system for new financial institutions, reducing bank reserve requirements and state ownership in the banking sector, and abolishing other administrative restrictions (Abiad et al., 2008).[3]

Financial deregulation may destabilize money demand and undermine the usefulness of monetary aggregates in monetary policy (McCallum, 1985; Issing, 1997). For instance, deregulation of interest rates and abolishment of credit rationing in advanced countries in the 1980s freed banks in their credit activities, increased the competitiveness of the banking sector and financial intermediaries, and made it difficult for central banks to control domestic credit (Argy et al., 1990). These changes resulted in higher than targeted money growth and weaker relationships between targeted aggregates, GDP, and inflation. Consequently, central banks could not ensure price stability and were forced to leave MT. Our next hypothesis is:

Hypothesis 3: *Financial deregulation increases the probability to abandon MT.*

After the introduction of MT, Germany did not experience considerable changes in its financial regulatory framework (Issing, 1997). As a result, it preserved a stable relationship between monetary aggregates and inflation. Meanwhile, financial deregulation in the 1980s in Switzerland made monetary conditions unstable and reduced the effectiveness of MT (Rich, 1997).

## Financial development

Another possible cause of MT abandonment is the development of financial markets. The emergence of credit and various money substitutes, especially interest-bearing ones, and their intensive circulation increase the income velocity of money, which in turn affects the transactions demand for money, making it unstable in the long run (Bordo and Jonung, 1990; Tan, 1997). This hinders central banks' control of money growth and undermines the effec-

[3] Financial deregulation is sometimes confused with financial innovation. While the former refers to the removal of restrictions and controls in the financial system, the latter captures technological advances that improve the access to information and processing of financial transactions as well as create new financial products, services and market segments (Tufano, 2003; Gropp et al., 2007). While financial innovation is driven by deregulation (Gropp et al., 2007), financial regulation can also lead to innovations, e.g. efficient deposit insurance schemes, uniform accounting standards (De Haan et al., 2009). We do not include financial innovation in the analysis due to the lack of data on a suitable proxy for most of the analyzed countries.

tiveness of MT.

Note that money demand functions are found to be stable in several developing countries whose central banks are currently implementing MT.[4] These countries have relatively underdeveloped financial and banking sectors, with low ratios of stock market capitalization and bank credit to GDP. This could explain why their monetary conditions are still favorable for MT implementation. Thus, our fourth hypothesis is:

Hypothesis 4: *Financial system development increases the probability to abandon MT.*

Calderón and Schmidt-Hebbel (2008) find that countries with developed financial markets are more likely to leave MT.

### Financial dollarization

Emerging and developing countries often experience financial dollarization. This means that households, firms, and financial institutions prefer to hold their assets and liabilities in foreign currency (usually US dollars) to protect them from high domestic currency inflation and uncertain economic situations (Keller and Richardson, 2003; Levy-Yeyati, 2006). This alters capital and money flows in financial markets and increases the volatility of money demand, making it unstable (Levy-Yeyati, 2006). As a result, central banks have difficulties controlling the money stock. Monetary policy based on MT loses credibility as central banks miss money growth targets and fail to ensure price stability. Our final hypothesis is:

Hypothesis 5: *Financial dollarization increases the probability to abandon MT.*

The explanatory variables used to test the formulated hypotheses are described in section 2.4.

[4] Slok (2002), Nassar (2005), and Narayan et al. (2009) find that money demand functions for Bangladesh, India, Madagascar, Mongolia, Pakistan, and Sri Lanka are stable in the long run.

## 2.3 Methodology

Our empirical approach is based on event history analysis which examines the probability of an event occurring at the observed time.[5] At each time period a central bank can be in one of two states: state 0 corresponds to implementation of MT strategy, while state 1 corresponds to an alternative, non-monetary targeting (nMT) strategy. The event of interest is the abandonment of MT, i.e. the switch to an nMT strategy. As central banks generally do not return to MT after they leave it, MT becomes a non-recurrent state. This implies that the probability of switching from nMT to MT is zero, while the probability to continue pursuing nMT strategy is one. Here, we focus on a single event of MT abandonment and examine how its likelihood depends on different determinants.

In order to analyze time-series cross-section data with a binary dependent variable, we apply panel binary choice models.[6] We use the logit specification as it constraints probabilities to lie within the unit interval and produces good statistical inference.

In each year one of two outcomes takes place: the central bank abandons MT or it does not. Let $y_{it}$ be a binary dependent variable that takes the value 0 if a central bank of country $i$ implements MT in year $t$ (the event does not occur) and 1 if it abandons MT in year $t$ (the event occurs). The corresponding observation rule is:

$$y_{it} = \begin{cases} 1 & \text{if} \quad y^*_{it} > 0 \\ 0 & \text{if} \quad y^*_{it} \leq 0 \end{cases}, \tag{2.2}$$

where $y^*_{it}$ is the unobserved latent variable.

The underlying model for the latent variable is:

$$y^*_{it} = \alpha + \boldsymbol{\beta}' \boldsymbol{EXP}_{i,t-1} + \boldsymbol{\gamma}' \boldsymbol{CTR}_{i,t-1} + \mu_i + \varepsilon_{it}, \quad i = 1, \ldots, N; \; t = 1, \ldots, T_i, \tag{2.3}$$

[5] The event history analysis for time-series cross-section data with a binary dependent variable is described in Beck et al. (1998).

[6] The econometric methodology used in this chapter is described in Cameron and Trivedi (2005, Chapter 23) and Baltagi (2008, Chapter 11).

where $T_i$ is the year of MT abandonment for those countries that left MT, and the last year in the sample (i.e. 2009) for countries that did not leave MT during the analyzed period. $\alpha$ is a constant term; $\boldsymbol{\beta}$ and $\gamma$ are vectors of parameter estimates; $\mu_i$ are country-specific effects; $\varepsilon_{it}$ is the error term that follows a logistic distribution; $\boldsymbol{CTR}_{i,t-1}$ is a matrix of control variables; $\boldsymbol{EXP}_{i,t-1}$ is a matrix of explanatory variables, including: financial liberalization (*Lib*), exchange rate regime (*Exr*), the interaction term of exchange rate regime with liberalization, financial deregulation (*Der*), financial development (*Dev*), and financial dollarization (*Dol*):

$$\begin{aligned}\boldsymbol{\beta}'\boldsymbol{EXP}_{i,t-1} \equiv \beta_1 Lib_{i,t-1} + \beta_2 Exr_{i,t-1} + \beta_3 (Exr \times Lib)_{i,t-1} \\ + \beta_4 Der_{i,t-1} + \beta_5 Dev_{i,t-1} + \beta_6 Dol_{i,t-1}.\end{aligned} \tag{2.4}$$

All the control and explanatory variables are lagged one year as the current decisions of central banks to give up MT rely on the available history of macroeconomic, financial, and other indicators.

The probability to abandon MT in year $t$ is formulated as follows:

$$\begin{aligned}&\Pr(y_{it} = 1 | \boldsymbol{EXP}_{i,t-1}, \boldsymbol{CTR}_{i,t-1}, \mu_i) = \\ &\quad \Lambda(\alpha + \boldsymbol{\beta}'\boldsymbol{EXP}_{i,t-1} + \boldsymbol{\gamma}'\boldsymbol{CTR}_{i,t-1} + \mu_i),\end{aligned} \tag{2.5}$$

where $\Lambda(.)$ denotes the logistic cumulative distribution function.

The important modeling step in panel data analysis includes the treatment of country-specific effects $\mu_i$ that control for unobserved cross-country heterogeneity. Depending on the assumptions about these effects, we may distinguish three model specifications:

1. The coefficient estimate and variance of $\mu_i$ are insignificant. In this case we estimate a pooled-data logit model.

2. $\mu_i$ are random effects, uncorrelated with the regressors: $\mu_i | \boldsymbol{EXP}_{i,t-1}, \boldsymbol{CTR}_{i,t-1} \sim \mathcal{N}(0, \sigma_\mu^2)$. The appropriate model is the random effects logit model.

3. $\mu_i$ are fixed effects, correlated with the regressors. With large $N$, the

presence of fixed effects causes the incidental parameters problem, as the number of parameters increases with the number of countries in the sample (Baltagi, 2008). This problem is eliminated by estimating the conditional fixed effects logit model (Cameron and Trivedi, 2005; Baltagi, 2008).[7]

To examine which model specification fits the data better, we estimate all three types of logit and compare them by using a Hausman test. The models are estimated by Maximum Likelihood.

The described models have their advantages and drawbacks. Pooled-data and random effects logit models use the full sample for estimation, but their results are inconsistent in the presence of fixed effects. Fixed effects logit produces consistent and efficient parameter estimates when unobserved country-specific effects are correlated with regressors. However, it drops the entire control group, i.e., countries that have not left MT at the end of the analyzed period. In addition, while fixed effects logit models describe the variation in the data observed *within* countries, pooled-data and random effects logit models explain the variation observed both *within* and *between* countries (Baltagi, 2008, Chapter 11). This comparison is important for the interpretation of estimation results.

Another methodological issue refers to the analysis of interaction effects. It is not possible to interpret the interaction effect in nonlinear models by simply examining the coefficients on constituent variables and their interaction term (Brambor et al., 2006). Therefore, we follow the approach of Ai and Norton (2003) and Brambor et al. (2006) to calculate the correct interaction effect. The total marginal effect of the exchange rate regime on the likelihood to leave MT, conditional on capital mobility (financial liberalization), is measured as:

$$\frac{\partial \Lambda(.)}{\partial Exr_{i,t-1}} = (\beta_2 + \beta_3 Lib_{i,t-1}) \times \Lambda(.) \tag{2.6}$$

[7] However, for the panel probit model the incidental parameter problem cannot be avoided. There is no fixed effect probit estimator that would produce consistent parameter estimates. For this reason we use the logit specification.

The interaction effect and its significance can vary for different levels of capital mobility. We cannot compute the interaction effect as in (2.6) for fixed effects logit because marginal effects in this model depend on values of $\mu_i$. Hence, we evaluate and present the interaction effect only for pooled logit.

Since we analyze the probability of leaving MT, we only retain observations for countries from the start of MT until the year of its abandonment.

## 2.4 Data description

### Country sample

Our sample consists of 35 countries that implemented MT over the period 1975–2009. We include two groups of MTers: 24 countries that implemented and abandoned MT in the analyzed period (MT-'leavers') and 11 countries that continue implementing MT (MT-'stayers').[8] The latter serves as a control group. Time-series observations for each country start in the year of MT adoption and end in the year of its abandonment (year 2009 for MT-'stayers'). Duration of MT varies from 4 to 29 years in different countries. Consequently, the panel dataset is unbalanced. Table 2.1 lists MT countries and shows the dates of adoption and (where applicable) abandonment of MT. According to the IMF classification, we distinguish 13 advanced and 22 emerging and developing MT countries.

### Independent variables

To test the hypotheses formulated in section 2.2, we include five explanatory variables in the model. As a proxy for financial liberalization, we employ the Chinn-Ito index of capital account openness (Chinn and Ito, 2008). The index uses the information on the restrictions on cross-border financial transactions reported by the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions. To examine the conditioning effect of capital mobility, we include an interaction term of the exchange rate regime with financial

[8] A similar division of MT countries is used by Calderón and Schmidt-Hebbel (2008) who distinguish 'MT movers' and 'MT stayers'.

Table 2.1. **List of countries with dates of MT adoption and abandonment**

| Countries that implemented and abandoned MT (MT-'leavers') | | | Countries that did not abandon MT (MT-'stayers') | |
|---|---|---|---|---|
| Advanced (13) | | | Advanced (0) | |
| Country | Dates[a] | Post-MT monetary policy strategy | Country | Dates |
| Australia | 1976-1985 | inflation targeting (from 1993) | | |
| Canada | 1976-1983 | inflation targeting (from 1991) | | |
| France | 1977-1999 | ECB strategy (from 1999) | | |
| Germany | 1975-1999 | ECB strategy (from 1999) | | |
| Greece | 1975-1998 | ECB strategy (from 2001) | | |
| Italy[b] | 1985-1999 | ECB strategy (from 1999) | | |
| Japan | 1978-1999 | implicit price stability anchor (from 2001) | | |
| Korea | 1979-1998 | inflation targeting (from 1998) | | |
| Slovenia | 1997-2001 | exchange rate targeting (2001-2006), ECB strategy (from 2007) | | |
| Spain | 1978-1995 | inflation targeting (1995-1998), ECB strategy (from 1999) | | |
| Switzerland | 1975-2000 | inflation targeting (from 2000) | | |
| United Kingdom | 1976-1992 | inflation targeting (from 1993) | | |
| United States | 1975-1996 | implicit price stability anchor (from 1996) | | |
| Emerging and developing (11) | | | Emerging and developing (11) | |
| Albania | 1993-2006 | transition to inflation targeting (from 2006) | Bangladesh | 2003-on |
| Egypt | 1996-2005 | transition to inflation targeting (from 2005) | China | 1994-on |
| Ghana | 1992-2007 | inflation targeting (from 2007) | Madagascar | 1994-on |
| Guatemala | 1993-1996 | multiple targets (1996-2004), | Mongolia | 1995-on |
| | | inflation targeting (from 2005) | Mozambique | 1992-on |
| India | 1985-1998 | multiple indicators (from 1998) | Nigeria | 1986-on |
| Indonesia[c] | 1997-2005 | inflation targeting (from 2005) | Pakistan[b] | 1995-on |
| Moldova | 1994-2009 | transition to inflation targeting (from 2009) | Sri Lanka | 1981-on |
| Philippines | 1985-1995 | transition to inflation targeting (1995-2001), | Tanzania | 1995-on |
| | | inflation targeting (from 2002) | Tunisia | 1987-on |
| Russia | 1993-2004 | multiple targets (from 2004) | Uganda | 1993-on |
| South Africa | 1986-2000 | inflation targeting (from 2000) | | |
| Thailand[c] | 1997-2000 | inflation targeting (from 2000) | | |

*Notes:* Analyzed sample does not include several countries that are mentioned in the IMF De Facto Classification of Exchange Rate Regimes and Monetary Policy Frameworks, but for which we are unable to identify the exact dates of adoption (and abandonment) of MT.
[a] The first date refers to the adoption year; the second date – to the year of MT abandonment.
[b] Italy applied direct credit targeting during 1974-1984, in 1985 it started targeting M2; similarly, Pakistan used credit ceilings and targets during 1973-1994, in 1995 M2 became an official monetary target.
[c] These countries adopted base money targeting under the IMF-supported program for the post-Asian crisis economic recovery.

Sources: Argy et al. (1990), Houben (1997, 1999), Sterne (2001), Festić (2002), Fatás et al. (2004), Stone and Bhundia (2004), Fane (2005), Nassar (2005), Al-Mashat and Billmeier (2007), Patra and Kapur (2012), IMF De Facto Classification of Exchange Rate Regimes and Monetary Policy Frameworks, and central banks' publications.

liberalization. The exchange rate regime indicator is based on the de facto 'fine' classification of Reinhart and Rogoff (2004).

The financial deregulation index is based on the dataset of Abiad et al. (2008) and includes five dimensions of financial reforms: credit controls and reserve requirements, interest rate controls, entry barriers, privatization of banking sector, and government policies towards securities' markets.[9] A higher value of the index indicates more deregulation.

Following Levine et al. (2000) and Beck et al. (2009), financial development is measured by the ratio of domestic credit provided by the banking sector to GDP.

De Nicoló et al. (2003) distinguish three types of dollarization: payment dollarization corresponds to the use of foreign currency in transactions; financial dollarization refers to residents' holdings of financial assets and liabilities in foreign currency; and real dollarization implies indexing of prices in foreign currency. Given these definitions, it would be suitable for our analysis to use the proxy for financial dollarization, measured as the ratio of foreign currency deposits to total bank deposits. The data for this measure is compiled from the Financial Dollarization Dataset of Levy-Yeyati (2006), as well as national statistics. However, this variable is missing for 49% of all observations in our sample. Therefore, we substitute deposit dollarization with a reserves' dollarization proxy (the ratio of foreign currency reserves to total reserves), which is available for the whole sample. The shortcoming of this measure is that it reflects payment dollarization (De Nicoló et al., 2003) and that it is not strongly linked to deposit dollarization (correlation between these proxies is 0.21).[10] To test the robustness of results to different specifications of dollarization, we include reserves' dollarization in the

[9] The financial reform index of Abiad et al. (2008) includes also capital account liberalization and banking sector supervision. However, these dimensions are excluded from our indicator. Capital account liberalization is measured by the Chinn-Ito index; and banking sector supervision does not fit the definition of financial deregulation.

[10] Although payment dollarization does not necessarily lead to financial dollarization, high reserves' dollarization combined with pegged exchange rates can encourage financial dollarization due to market failures, foreign currency deposit insurance, and extensive government guarantees to bank creditors (De Nicoló et al., 2003).

main analysis and deposit dollarization — in the sensitivity analysis.

Table A.1 in the Annex provides a detailed description of all variables and their data sources.

### Control variables

Apart from explanatory variables, we include six control variables that capture macroeconomic, fiscal, and institutional factors potentially associated with MT abandonment.

The first control variable is the log of real GDP per capita measuring the level of economic development. Economic development is strongly related to financial development (De Haan et al., 2009). In addition, Calderón and Schmidt-Hebbel (2008) argue that MT is more often implemented in emerging and developing countries than in advanced ones. Due to the failure of MT to ensure price stability and due to the accession of some MT countries to the EMU, this strategy disappeared in the monetary policy framework of advanced countries by the late 1990s and is currently used only by emerging and developing economies (Roger, 2009). Thus, higher economic development is expected to increase the probability to give up MT.

Next, we include the CPI inflation rate, transformed as $\frac{\pi/100}{1+\pi/100}$ to reduce the impact of extreme inflation observations. During the 1970s, advanced countries experienced high inflation caused by oil price shocks and followed by volatile growth of monetary aggregates. Several countries used money growth targets to achieve price stability (Argy et al., 1990; Rich, 1997; von Hagen, 1999). However, once inflation was brought down to sustainable levels, countries preferred to switch to alternative monetary strategies (such as inflation targeting) that helped to maintain low and stable inflation. Thus, we expect a negative impact of inflation on the probability to leave MT.

Previous studies emphasize that successful implementation of MT requires the existence of a strong relationship between monetary aggregates and inflation (Argy et al., 1990; Issing, 1997; Mishkin and Estrella, 1997; Houben, 1999; Mishkin and Savastano, 2001). High money growth volatility makes this relationship weaker and less predictable in the long run. It increases the risk of missing money growth targets and jeopardizes the effectiveness of MT. Money growth volatility is measured by 3-year rolling standard deviations of annual money growth rates.

We introduce trade openness measured as the sum of exports and imports (in percentage of GDP) as a proxy for the external exposure of an economy. Open economies that are vulnerable to commodity prices and exchange rate shocks often prefer to focus on exchange rate stability rather than price stability. Moreover, external shocks may destabilize the relationship between monetary aggregates and inflation, which will increase the risk of MT abandonment.

The last two control variables are fiscal and institutional. We include the general government fiscal balance (in percentage of GDP) as a proxy for fiscal discipline. In order to pursue credible monetary policy through controlling money growth, central banks should not be forced to finance fiscal deficits (Mishkin and Savastano, 2001). Inadequate fiscal discipline could cause poor monetary policy decisions and, consequently, lead to the failure of MT in reaching price stability. Fiscal balance is expected to have a negative effect on the probability to abandon MT.

Central bank independence is a relevant institutional factor. Central banks with low political and economic independence are vulnerable to political pressure for higher inflation to stimulate short-term economic growth (Mishkin, 2006). This makes any monetary strategy unsuccessful in achieving price stability. MT central banks with low independence are especially ineffective as their ultimate goal of low inflation is linked to the intermediate money growth target (McCallum, 1985), and the actual money growth could be manipulated by central banks facing government pressure. Measuring central bank independence is difficult, especially for emerging and developing countries. The legal index of central bank independence may be a poor proxy for actual independence, as it is based on central bank laws in place. Many central banks in emerging and developing countries do not fully respect the rule of law. For this reason, we construct the actual central bank independence (ACBI) index as an interaction term of the legal index and the rule of law. The legal index is based on the data of Arnone et al. (2007) and includes political and economic aspects of central bank independence. Using the method of Klomp and de Haan (2010) to pinpoint the exact year when the change in legislation enhanced central bank independence, we use the information in Cukierman et al. (2002) and Acemoglu et al. (2008) on major changes of central bank laws. The rule of law is based on the Law and Order index of the International Country Risk Guide (ICRG) database.

### Imputation of missing observations

Before carrying out the estimations, we have to deal with missing observations. The data for five variables (financial liberalization, financial deregulation, financial development, money growth volatility, and rule of law) are missing for some years in the sample. The percentage of missing observations on these variables ranges from 1% to 17% of all observations. We apply the Expectation-Maximization (EM) algorithm introduced by Dempster et al. (1977) and described by Schafer (1997). It is a standard imputation technique for filling in missing observations.

Following Schafer (1997), the log-likelihood of the complete data $\Omega$ can be written as:

$$\ln P(\Omega|\theta) = \ln P(\Omega_{obs}|\theta) + \ln P(\Omega_{mis}|\Omega_{obs}, \theta), \tag{2.7}$$

where $\ln P(\Omega|\theta)$ denotes the log-likelihood of the complete data, $\ln P(\Omega_{obs}|\theta)$ is the log-likelihood of the observed data, and $\ln P(\Omega_{mis}|\Omega_{obs}, \theta)$ is the predicted distribution of the missing data given $\theta$. $\Omega, \Omega_{obs}$, and $\Omega_{mis}$ are the matrices of the complete data, the observed part of data, and the missing part of data, respectively. $\theta$ are parameters of the missing-data distribution. As $\Omega_{mis}$ is unknown, we can only calculate expectations of the log-likelihood of the complete data given the estimates of $\theta$.

The imputation procedure is the following. First, we choose initial values for $\theta$ and calculate the distribution of the missing data based on those values. Next, we iterate the EM algorithm that involves two steps: the expectation step (E-step) and the maximization step (M-step). In the E-step, the conditional expectation of the log-likelihood of the complete data in (2.7) is constructed given the likelihood of the observed data and the predicted distribution of the missing data. In the M-step, the parameters $\theta$ are re-estimated by maximizing the log-likelihood of the complete data from the E-step. The algorithm is repeated until the estimates converge. Dempster et al. (1977) prove that the algorithm converges to the unique global maximum of the log-likelihood of the observed data.[11]

We use the EM algorithm of SPSS, under the assumption that the data are normally distributed.[12]

### Descriptive statistics – mean comparison tests

Table 2.2 reports the mean comparison tests for all independent variables. We compare the means of variables in two country groups: MT-'leavers' and MT-'stayers'. We apply a two-sided mean comparison t-test, where the null hypothesis is that the mean difference of two groups is zero: $H_0$: *mean (MT-'leavers')* $-$ *mean (MT-'stayers')* $= 0$. The alternative hypothesis is that the mean difference is not zero. We perform mean comparison tests for unequal variances of variables in two groups.[13]

The statistics show that MT-'leavers' have on average more liberalized, deregulated and developed financial systems as well as more flexible exchange rate regimes than MT-'stayers'. Additionally, MT-'leavers' are characterized by lower dollarization than MT-'stayers'. The mean differences of all financial variables are statistically significant.

Regarding the control variables, on average MT-'leavers' are more developed and less open. MT-'leavers' do not differ statistically from MT-

[11] Since the EM algorithm imputes missing observations based on the observed data only, using the complete dataset, obtained after imputation, in regression models should not distort estimation results.

[12] We also applied the EM algorithm assuming mixed normal distribution and t distribution. However, these specifications did not produce sensible imputation results.

[13] The Bartlett's test statistic rejects the null hypothesis of equal variances, indicating that two groups have unequal variances for each variable. The exceptions are trade openness and fiscal balance, for which the variances are equal; we use the mean comparison test for equal variances in these two cases.

Table 2.2. **Descriptive statistics — mean values comparison**

| Variable | MT-'leavers' | MT-'stayers' | P-value |
|---|---|---|---|
| Financial liberalization | 0.63 | -0.52 | 0.00 |
| Financial deregulation | 10.03 | 9.27 | 0.01 |
| Financial development | 0.90 | 0.38 | 0.00 |
| Financial dollarization | 0.73 | 0.96 | 0.00 |
| GDP per capita (ln) | 8.67 | 6.26 | 0.00 |
| Inflation | 0.09 | 0.10 | 0.24 |
| Exchange rate regime | 9.37 | 8.03 | 0.00 |
| Money growth volatility | 7.17 | 7.78 | 0.55 |
| Trade openness | 52.19 | 65.38 | 0.00 |
| Fiscal balance | -3.72 | -4.13 | 0.18 |
| Central bank independence | 2.34 | 1.77 | 0.00 |
| Number of observations | 360 | 195 | |

*Notes:* Table 2.2 reports means of independent variables in each MT group. For MT-'leavers', the statistics are calculated for the period of MT practice from adoption until abandonment. For MT-'stayers', we use the period from MT adoption until the end of 2009. P-value$<$ 0.05 indicates the rejection of the null hypothesis and suggests that the mean difference of a particular variable is statistically significant at the 5% level.

'stayers' in terms of money growth volatility, inflation and fiscal balance. Finally, MT-'leavers' have higher actual central bank independence than MT-'stayers'. Note that if the legal independence index is used instead of the actual one, we find no significant mean difference between the groups.

### Correlation analysis

We perform a correlation analysis to check for potential multicollinearity between the independent variables (see Tables A.2 and A.3 in the Annex). For the full sample (Table A.2), most variables are not highly correlated with each other. However, there is a high and significant correlation between the economic development proxy and financial development. Apparently, more economically developed countries have better developed financial markets.[14] To avoid multicollinearity, we include these variables in model estimations separately.

For the subsample of MT-'leavers' (Table A.3), high correlation is detected between economic development and two variables: financial liberalization and financial development. These financial determinants will be included in the fixed effects logit model without the economic development proxy. A similar approach is used with respect to the ACBI index that is highly correlated with financial liberalization.

## 2.5 Empirical results

This section discusses the main estimation results. The Hausman test, which compares the estimates of fixed effects with random effects logit, rejects the random effects null hypothesis in favor of the fixed effects model. Therefore, we report only the results of the pooled-data logit model for both *within* and *between* countries variation and the fixed effects logit model for only *within* countries variation. Likelihood Ratio tests conducted on the residuals of pooled-data logit indicate the presence of heteroscedasticity and autocorrelation. Hence, we use robust standard errors clustered on the country level.

When estimating a panel data model with large $T$, one should take into account the potential time dependency problem. This means that the probability of a country to abandon MT in year $t$ may depend on the duration of MT in this country. Ignoring temporal dependence may lead to the underestimation of standard errors and too optimistic statistical inference (Beck et al., 1998). To deal with this problem, we follow the approach of Beck et al. (1998). First, we add time dummies marking the number of years since MT adoption. Another technique is to use cubic splines that smooth time dummies. We include in a model three cubic splines and a variable measuring the number of years since MT adoption. The results show that these dura-

[14] De Haan et al. (2009, Chapter 1) review studies which show that financial development has a positive impact on economic growth and development.

tion variables as well as time dummies are (individually and jointly) insignificant. Therefore, we do not include them in our final specification.[15]

As pooled-data and fixed effects logit models explain different types of variation in the data, it is difficult to compare their estimates. Thus, we interpret them separately. Table 2.3 presents the results of pooled-data logit estimation. For this model we report average marginal effects since coefficient estimates cannot be interpreted directly.[16] Columns (1)-(2) show the estimation results without the interaction term, while estimations in columns (3)-(5) include the interaction term. Additionally, in columns (2), (4) and (5) we exclude from the model either financial development or economic development as these variables are highly correlated with each other.

The findings from pooled-data logit suggest that most of the analyzed financial characteristics play a significant role in MT abandonment. There is strong evidence that countries which deregulate their financial systems and liberalize capital movements during the period of MT use are more likely to leave MT. Additionally, the marginal effect of reserves' dollarization is significant with a positive sign, indicating that more dollarized economies have a higher probability to abandon MT. Financial deregulation, liberalization, and dollarization destabilize money demand and make the growth of monetary aggregates less predictable. This jeopardizes the effectiveness of MT in reaching its targets.

The interaction term is significant with a negative sign in all the models. Figure 2.1 illustrates how the exchange rate regime influences the probability to abandon MT, depending on the level of financial liberalization. For low levels of liberalization, the marginal effect is positive (left side of the graph), implying that countries with flexible exchange rates are more likely to give up MT. Thus, money growth targets can be still used by countries under fixed exchange rate arrangements, given that they restrict capital flows. The opposite conclusion is drawn when capital mobility is high (right side of

[15] The estimation results with duration variables are available on request.

[16] Average marginal effects are calculated as averages (over $N$ and $T$) of individual marginal effects. Standard errors of these marginal effects are computed using the delta method (Cameron and Trivedi, 2005, Chapter 14).

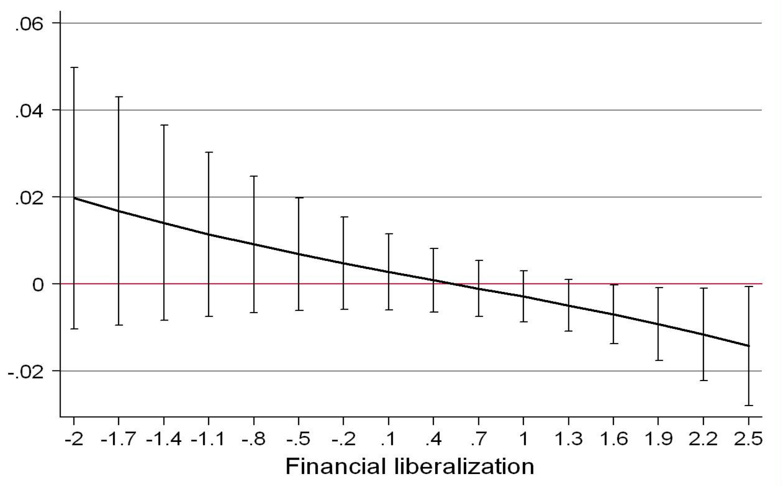
Table 2.3. **Determinants of MT abandonment — pooled-data logit**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Financial liberalization | 0.004 | 0.004 | 0.051 ** | 0.050 ** | 0.045 ** |
| | (0.010) | (0.010) | (0.021) | (0.020) | (0.019) |
| Exchange rate regime | −0.004 | −0.004 | 0.003 | 0.003 | 0.002 |
| | (0.003) | (0.003) | (0.004) | (0.004) | (0.004) |
| Exchange rate regime × | | | −0.006 *** | −0.006 *** | −0.005 ** |
| Financial liberalization | | | (0.002) | (0.002) | (0.002) |
| Financial deregulation | 0.011 ** | 0.011 ** | 0.007 * | 0.007 * | 0.008 ** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Financial development | −0.003 | | −0.005 | | 0.016 |
| | (0.022) | | (0.021) | | (0.016) |
| Financial dollarization | 0.110 ** | 0.107 ** | 0.169 *** | 0.165 *** | 0.116 *** |
| | (0.050) | (0.041) | (0.060) | (0.056) | (0.053) |
| Economic development | 0.009 | 0.008 | 0.015 * | 0.014 * | |
| | (0.008) | (0.006) | (0.009) | (0.008) | |
| Inflation | −0.158 | −0.150 | −0.248 | −0.235 | −0.210 |
| | (0.215) | (0.216) | (0.200) | (0.198) | (0.195) |
| Money growth volatility | −0.002 | −0.002 | −0.002 | −0.002 | −0.002 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) |
| Trade openness | 0.000 | −0.0001 | −0.0001 | −0.0001 | −0.0001 |
| | (0.0004) | (0.0004) | (0.005) | (0.005) | (0.0001) |
| Fiscal balance | −0.002 | −0.002 | −0.001 | −0.001 | −0.001 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Central bank independence | −0.002 | −0.002 | 0.002 | 0.002 | 0.003 |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.012) |
| Number of observations | 520 | 520 | 520 | 520 | 520 |
| Log-likelihood | −86.77 | −86.78 | −83.54 | −83.57 | −84.55 |
| Wald $\chi^2$ | 22.44 ** | 23.08 ** | 23.18 ** | 23.93 ** | 24.09 ** |

*Notes:* The table reports average marginal effects and their robust standard errors (in parentheses) computed using the delta method. ***, **, and * indicate significance at the 1%, 5%, and 10% significance level, respectively. The Wald $\chi^2$ test is equivalent to the F-test in linear regressions and evaluates the goodness-of-fit of the model.

the graph). Here the marginal effect is negative. This suggests that countries with flexible exchange rate regimes are less likely to abandon MT; hence, it is not possible to have both fixed exchange rates and money growth targets. Our results are in line with the *policy trilemma* hypothesis. The interaction effect is significant for high levels of financial liberalization (between 1.3 and 2.5), that counts for 28% of all observations in our sample.

Figure 2.1. **The effect of exchange rate regime on the likelihood to abandon MT conditional on financial liberalization**




*Notes:* The solid line shows the total marginal effect of exchange rate regime on the probability to leave MT at different levels of financial liberalization; vertical boundaries indicate the 95% confidence interval. The marginal effect is significant when the solid line and confidence intervals are above (below) zero.

Our findings from pooled-data logit support hypotheses $H_1$, $H_2$, $H_3$, and $H_5$, and reject hypothesis $H_4$. As for the control variables, we find that economically developed countries are more likely to abandon MT. The marginal effects of other variables are insignificant.

Next, we estimate the fixed effects logit model. This model discards the entire group of MT-'stayers' and explains the variation of determinants for MT abandonment *within* MT-'leavers'. Since in fixed effects logit models marginal effects depend on values of $\mu_i$, they cannot be computed. Hence, we report coefficient estimates instead. Their signs correspond to the signs of marginal effects.[17] Table 2.4 reports the estimation results. Columns (1)-(2) show the estimations without the interaction term, while columns (3)-(4) include the interaction term. Since financial development is highly correlated with economic development, we include these variables in the estimation separately: columns (1) and (3) report the results for models without economic development, and columns (2) and (4) models without financial development.[18]

The results show that the coefficient estimates of financial development and financial deregulation are significant with a positive sign, suggesting that reforms and development in the financial systems of MT-'leavers' increase their probability to abandon MT. The coefficient estimates of financial liberalization, exchange rate regime and their interaction term are insignificant. The outcomes confirm hypotheses $H_3$ and $H_4$; other hypotheses are rejected.

The coefficient estimate of economic development is significant with a positive sign implying that more developed MT-'leavers' are more likely to leave MT. This result is in line with previous studies claiming that advanced countries do not practice MT anymore and that this strategy is currently implemented only in emerging and developing economies (Roger, 2009).

Our findings indicate that lower inflation significantly increases the likelihood of MT-'leavers' to abandon MT. Central banks that achieve low inflation prefer to maintain price stability with the help of a different monetary strategy than MT. Note that out of 24 MT-'leavers' in our sample, 12 countries adopted inflation targeting after they left MT and another 3 countries are preparing to adopt inflation targeting as a strategy to maintain inflation

[17] For logit models the marginal effect of a change in a regressor on the conditional probability is calculated as:

$$\frac{\partial P[Y_{it}=1|X]}{\partial x_k} = \Lambda'(X,\alpha,\beta,\gamma,\mu_i)\beta_k.$$

$\Lambda'(z) = \frac{\partial \Lambda(z)}{\partial z} > 0$, so the sign of the marginal effect depends only on $\beta_k$.

[18] As financial liberalization is highly correlated with the ACBI index, we estimated models without the ACBI index and models without financial liberalization. That did not change the significance and signs of independent variables. These results are available on request.

Table 2.4. **Determinants of MT abandonment — fixed effects logit**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Financial liberalization | 1.162 | 1.243 | 2.084 | 5.347 |
| | (1.310) | (2.303) | (1.740) | (8.701) |
| Exchange rate regime | −0.066 | −0.545 | 0.104 | 0.600 |
| | (0.170) | (0.450) | (0.264) | (1.421) |
| Exchange rate regime × | | | −0.113 | −0.557 |
| Financial liberalization | | | (0.130) | (0.661) |
| Financial deregulation | 1.160 * | 1.950 | 1.077 * | 1.746 |
| | (0.642) | (1.825) | (0.604) | (1.540) |
| Financial development | 17.040 ** | | 17.140 ** | |
| | (6.984) | | (7.007) | |
| Financial dollarization | 9.060 | 19.820 | 9.648 | 16.420 |
| | (7.143) | (13.230) | (7.323) | (12.400) |
| Economic development | | 233.800 * | | 206.100 * |
| | | (122.600) | | (117.800) |
| Inflation | −52.050 ** | −294.200 * | −50.190 ** | −246.200 |
| | (21.730) | (169.000) | (21.170) | (175.800) |
| Money growth volatility | −0.066 | −0.074 | −0.070 | 0.004 |
| | (0.071) | (0.122) | (0.074) | (0.179) |
| Trade openness | 0.110 | 0.614 * | 0.099 | 0.505 |
| | (0.082) | (0.348) | (0.080) | (0.357) |
| Fiscal balance | −0.440 * | −2.180 * | −0.356 | −1.798 |
| | (0.246) | (1.129) | (0.267) | (1.158) |
| Central bank independence | 1.716 | −0.614 | 1.766 | −0.867 |
| | (1.177) | (3.430) | (1.221) | (1.802) |
| Number of observations | 336 | 336 | 336 | 336 |
| Log-likelihood | −21.68 | −7.37 | −21.28 | −6.67 |
| Likelihood Ratio $\chi^2$ | 76.21 *** | 104.80 *** | 77.03 *** | 106.20 *** |

*Notes:* The table reports coefficient estimates and their standard errors (in parentheses). ***, **, and * indicate significance at the 1%, 5%, and 10% significance level, respectively. LR $\chi^2$ test is equivalent to the F-test in linear regressions and evaluates the goodness-of-fit of the model.

at the low sustainable level.

Money growth volatility is insignificant in all model specifications. This result is unexpected, given that the literature on MT assigns an important role to money demand stability as a crucial factor for the implementation of this strategy. Perhaps, the financial variables explain to some extent money demand stability and, therefore, serve as indirect determinants of MT abandonment. Also, our measure of money growth volatility might not be a strong indicator of money demand stability.

Our results also show that higher fiscal deficits significantly increase the probability of MT-'leavers' to abandon MT. The coefficient estimate of the ACBI index is insignificant, which implies that central bank independence is not a relevant prerequisite to leave MT. A more important aspect could be the transparency of a central bank in communicating its monetary policy strategy and money growth targets to the public. If central banks communicate monetary policy-making in an unclear way, their credibility is reduced and the effectiveness of MT in reaching price stability is undermined (Mishkin, 1999). Due to the limited availability of data on the transparency of central bank communication, we cannot incorporate this aspect into the analysis.

## 2.6 Sensitivity analysis

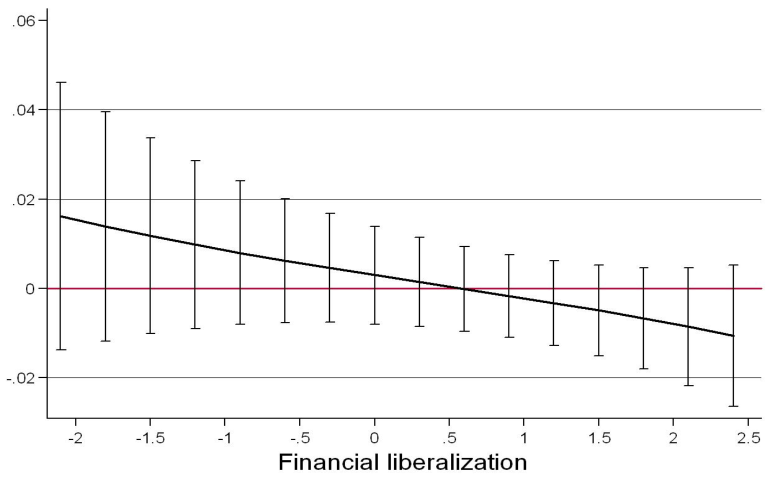
We investigate whether our findings are sensitive to the inclusion of countries in the analyzed sample, to estimations for sub-samples, and to adding and modifying variables. Most of the results are presented in Table 2.5. We report only pooled-data logit estimations as they use the full sample and are easier to interpret. Results for fixed effects logit are available on request.

First, we drop observations for four EMU countries (France, Germany, Greece, and Italy). These countries abandoned MT when they joined the euro area.[19] In this situation, abandoning MT was not caused by macroeconomic or financial factors but was a predetermined institutional agreement

[19] We do not drop observations for Spain, as its MT abandonment was followed by the adoption of inflation targeting in 1995. Inflation targeting was implemented in Spain until it joined the EMU in 1999.

of central banks to delegate the conduct and choice of monetary policy strategy to the European Central Bank (ECB). The estimation results for the sample without the mentioned EMU countries are shown in columns (1a)-(1b) of Table 2.5. The marginal effects of financial liberalization and dollarization remain significant with positive signs; financial deregulation becomes insignificant in the model with the interaction term. Figure 2.2 shows that the total marginal effect of the exchange rate regime conditional on financial liberalization is insignificant for all levels of liberalization. Thus, dropping the EMU countries from the sample does not lead to substantial changes of our main results except for making the interaction effect insignificant.

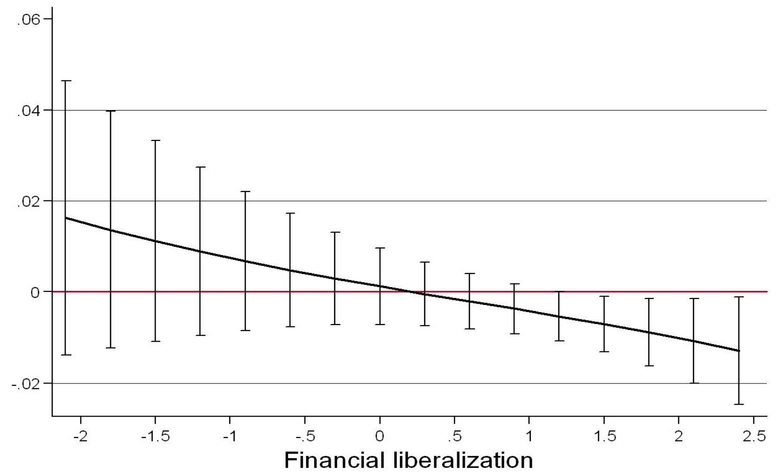
Figure 2.2. **The effect of exchange rate regime on the likelihood to abandon MT conditional financial liberalization (without 4 EMU countries)**




*Notes:* The solid line shows the total marginal effect of exchange rate regime on the probability to leave MT at different levels of financial liberalization; vertical boundaries indicate the 95% confidence interval. The marginal effect is significant when the solid line and confidence intervals are above (below) zero.

Second, we exclude observations for two South-East Asian countries, Indonesia and Thailand. These countries adopted money-based targeting under the IMF-supported program for economic recovery in the aftermath of the financial crisis in 1997–1998 (Fane, 2005). Here, MT was treated as a temporary institutional solution under crisis conditions rather than a monetary strategy with long-term objectives. The estimation results without these two countries are shown in Table 2.5, columns (2a)-(2b). The outcomes do not change substantially compared to Table 2.3. Financial liberalization, deregulation, and dollarization as well as economic development still have a significant impact on the probability to leave MT. Figure 2.3 shows that the total marginal effect of the exchange rate regime conditional on financial liberalization is significant with a negative sign for high levels of liberalization (between 1.2 to 2.5). Thus, our main conclusions are robust to the exclusion of Indonesia and Thailand.

Figure 2.3. **The effect of exchange rate regime on the likelihood to abandon MT conditional on financial liberalization (without Indonesia and Thailand)**




*Notes:* The solid line shows the total marginal effect of exchange rate regime on the probability to leave MT at different levels of financial liberalization; vertical boundaries indicate the 95% confidence interval. The marginal effect is significant when the solid line and confidence intervals are above (below) zero.

Third, we split the sample into advanced countries and emerging and developing ones. As splitting the dataset leads to fewer observations in each subsample, the results should be interpreted with caution. Since we divide the sample by an economic development criterion, we do not include the economic development proxy to control for country heterogeneity. Additionally, this variable is highly correlated with financial development and liberalization in both subsamples; therefore, including economic development could create a multicollinearity problem.

The results for advanced countries (Table 2.5, columns (3a)-(3b)) are comparable to the ones for the full sample. However, only financial dollarization and liberalization are relevant for the probability of advanced countries to leave MT and the interaction effect is only marginally significant (the graph does not show any significant areas; available on request).

The results for emerging and developing economies (Table 2.5, columns (4a)-(4b)) are different than those for the advanced countries. Financial deregulation and dollarization become insignificant, while the marginal effects of financial liberalization and development are significantly positive. Thus, emerging and developing countries that liberalize capital flows and develop financial systems during the period of MT practice are more likely to leave this monetary strategy. The interaction term is insignificant.

As an additional control variable, we include a nominal interest rate to test how a monetary policy instrument can influence the decision to abandon MT. An increase of the nominal interest rate may signal to the public that the central bank is committed to maintaining low inflation. Higher interest rates discourage banks from borrowing money; this can reduce money growth and help reach the monetary targets. As a result, the central bank might decide to continue MT instead of leaving it. The nominal interest rate is proxied by the discount rate, at which central banks lend money to commercial banks. The inclusion of this variable does not change the main results. The coefficient estimate of the interest rate is negative in all models and significant in pooled-data logit with the interaction term, for the full sample and for the subsample of emerging and developing countries. This implies that higher nominal interest rates decrease the probability (of emerging and developing countries, in particular) to give up MT. These results are available on request.

Finally, we re-estimate all models while including deposit dollarization instead of reserves' dollarization. The results are not substantially affected

Table 2.5. **Sensitivity analysis**

| | Without 4 EMU countries | | Without Indonesia and Thailand | | Advanced countries | | Emerging and developing countries | |
|---|---|---|---|---|---|---|---|---|
| | (1a) | (1b) | (2a) | (2b) | (3a) | (3b) | (4a) | (4b) |
| Financial liberalization | 0.003 | 0.044 * | 0.003 | 0.043 ** | 0.021 | 0.108 * | 0.013 * | 0.007 * |
| | (0.011) | (0.024) | (0.011) | (0.018) | (0.046) | (0.065) | (0.008) | (0.016) |
| Exchange rate regime | −0.001 | 0.003 | −0.005 * | 0.001 | −0.010 | 0.012 | 0.002 | 0.002 |
| | (0.005) | (0.005) | (0.003) | (0.004) | (0.008) | (0.011) | (0.003) | (0.003) |
| Exchange rate regime × Financial liberalization | | −0.005 ** | | −0.005 *** | | −0.011 ** | | 0.001 |
| | | (0.002) | | (0.002) | | (0.005) | | (0.002) |
| Financial deregulation | 0.008 * | 0.006 | 0.011 ** | 0.008 ** | 0.009 | 0.009 | 0.005 | 0.005 |
| | (0.005) | (0.004) | (0.004) | (0.004) | (0.009) | (0.011) | (0.003) | (0.004) |
| Financial development | −0.012 | −0.010 | −0.009 | −0.011 | −0.031 | −0.033 | 0.043 *** | 0.043 *** |
| | (0.031) | (0.026) | (0.023) | (0.022) | (0.040) | (0.040) | (0.012) | (0.012) |
| Financial dollarization | 0.149 ** | 0.164 *** | 0.112 ** | 0.158 ** | 0.246 * | 0.342 * | 0.083 | 0.075 |
| | (0.076) | (0.063) | (0.047) | (0.053) | (0.145) | (0.185) | (0.082) | (0.089) |
| Economic development | 0.015 | 0.017 * | 0.012 | 0.017 * | | | | |
| | (0.010) | (0.009) | (0.008) | (0.009) | | | | |
| Inflation | −0.102 | −0.203 | −0.035 | −0.126 | −0.823 | −0.778 | −0.132 | −0.129 |
| | (0.187) | (0.183) | (0.170) | (0.159) | (0.647) | (0.661) | (0.194) | (0.195) |
| Money growth volatility | −0.001 | −0.001 | −0.002 | −0.002 | −0.003 | −0.002 | −0.001 | −0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.003) | (0.002) | (0.002) |
| Trade openness | 0.000 | −0.0001 | −0.0002 | −0.0003 | 0.0002 | −0.0001 | 0.0003 | 0.0003 |
| | (0.001) | (0.001) | (0.000) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Fiscal balance | −0.003 | −0.002 | −0.001 | −0.001 | −0.007 | −0.008 | 0.003 | 0.003 |
| | (0.004) | (0.004) | (0.003) | (0.003) | (0.007) | (0.008) | (0.003) | (0.003) |
| Central bank independence | −0.001 | 0.001 | 0.000 | 0.003 | 0.005 | 0.011 | −0.017 | −0.017 |
| | (0.015) | (0.014) | (0.009) | (0.010) | (0.020) | (0.018) | (0.019) | (0.019) |
| Number of observations | 437 | 437 | 509 | 509 | 222 | 222 | 298 | 298 |
| Log-likelihood | −73.85 | −71.99 | −79.88 | −77.29 | −40.88 | −38.67 | −40.37 | −40.34 |
| Wald $\chi^2$ | 29.05 *** | 24.17 ** | 21.27 ** | 30.32 *** | 37.30 *** | 118.20 *** | 18.05 ** | 18.43 * |

*Notes:* The table reports average marginal effects and their robust standard errors (in parentheses). ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The Wald $\chi^2$ test evaluates the goodness-of-fit of the model. Columns (a) show the results without the interaction term, columns (b) — with the interaction term.

by this modification, but deposit dollarization is insignificant in all models.[20] Due to the limited data availability for deposit dollarization, the estimations are carried out on a much smaller sample. Consequently, the real impact of this variable could be largely underestimated. Nevertheless, the positive sign on its coefficient estimate suggests that higher deposit dollarization may increase the likelihood to leave MT.

The robustness analyses show that our main conclusions are to some extent sensitive to the modification and selection of countries. Particularly, the findings for emerging and developing countries differ from the ones for the full sample and advanced countries. This could be explained by considerable heterogeneity of the analyzed countries that practice MT.

## 2.7 Conclusion

This chapter investigates the role of financial system characteristics and reforms in the abandonment of MT by countries. Previous studies ignore financial system characteristics and empirical evidence on the determinants of MT abandonment is very limited. We formulate five hypotheses for financial system characteristics and include six control variables that are associated with countries' decisions to leave MT. We apply panel (pooled-data and conditional fixed effects) logit models to estimate the probability of abandoning MT.

The results of the analysis using pooled-data logit models, show that countries which experience liberalization, deregulation and dollarization in their financial systems are more likely to abandon MT. Moreover, the choice of the exchange rate regime influences the probability to give up MT differently conditional on the level of financial openness. Countries with limited capital mobility can use money growth targets and have fixed exchange rates at the same time. In addition, more economically developed countries are inclined to leave MT. The results of the analysis using fixed effects logit models, suggest that the probability of MT abandonment by MT-'leavers'

[20] These estimation results are available on request.

is affected by their financial development and deregulation. Also, more developed MT-'leavers' with past low inflation and larger fiscal deficits are more likely to leave MT.

The results are sensitive to the exclusion of some countries. Additionally, for advanced countries, financial liberalization and dollarization have a significant impact on the probability to leave MT. Meanwhile, financial liberalization and development contribute to the probability of MT abandonment by emerging and developing countries.

*Chapter 3*

# Inflation targeting: exploring the factors leading to adoption*

## 3.1 Introduction

Inflation targeting (hereafter, IT) was first introduced in 1989 in New Zealand as a monetary policy strategy. Since then, many countries started targeting inflation, since it was an attractive alternative to exchange rate pegs and money growth targets (Walsh, 2009). In the 1990s, mainly advanced countries adopted IT, but more recently also several emerging and developing economies have adopted IT. By the end of 2009, 31 countries adopted IT.

According to Mishkin and Savastano (2001), IT involves the public announcement of a numerical target for inflation, a strong commitment of the central bank to price stability as monetary policy objective, and a high degree of transparency and accountability. The distinctive feature of this strategy is a forward-looking decision-making process known as "inflation-forecast targeting" (Svensson, 1997). It means that an IT central bank sets its policy instruments in such a way that the inflation forecast (after some time) equals the inflation target.

The primary objective of IT is to ensure price stability through reaching the inflation target. Other goals (e.g., employment and exchange rate

* This chapter is based upon Samarina and de Haan (2014).

stability) should be subordinated to the inflation objective (Carare et al., 2002; Mishkin, 2004). Central banks commonly use a flexible IT framework, where output stabilization is also incorporated into the objective function of the central bank (Svensson, 1999). However, more weight is put on stabilizing inflation around its target. Due to the possible conflict between the inflation target and other goals, a central bank must be independent from government pressures and credible in its commitment to the price stability objective (Mishkin and Savastano, 2001; Freedman and Laxton, 2009).

IT has several benefits compared to other monetary policy strategies. First, IT reduces the time-inconsistency problem of monetary policy, which helps to achieve lower and less variable inflation (Mishkin and Savastano, 2001; Ball and Sheridan, 2004; Gonçalves and Salles, 2008). Second, IT enhances the credibility of a central bank and anchors inflation expectations thanks to its clear target as well as high transparency and accountability (Ball and Sheridan, 2004; Batini and Laxton, 2006). Third, IT offers more flexibility: inflation targets are set as a medium-term goal; consequently, short-term deviations from the target do not harm credibility (Batini and Laxton, 2006). Flexibility also allows stabilizing output without forgoing the inflation target. Finally, the economic costs of monetary policy failures are lower for IT than for other strategies. As the central bank increases interest rates to return inflation to its target, the costs are limited to a temporary higher inflation and slower growth (Batini and Laxton, 2006).

IT has also some potential drawbacks. First, IT involves setting hard targets for inflation. This could be a serious problem for emerging and developing countries which apply IT to bring down inflation from a very high level, as they are more likely to miss the targets and experience large inflation forecast errors (Mishkin, 1999). Second, IT could increase output volatility and lower economic growth. Third, IT does not provide immediate signals to the public about the stance of monetary policy due to the long lags in revealing inflation outcomes (Mishkin, 1999). Finally, IT does not allow policy-makers enough discretion to react to unexpected circumstances (Mishkin, 1999).

The literature on IT focuses mainly on the benefits from IT adoption, while less attention is devoted to analyzing the factors leading to IT adoption. Because of the increasing popularity of IT, there is a growing interest among academic researchers and policy makers in the feasibility of IT adoption in different countries. This motivates our research on the factors driving the decision of countries to adopt IT.

Previous research on IT adoption (as discussed in section 3.2) has several limitations. For instance, most studies have ignored financial system characteristics as possible factors leading to IT adoption. Furthermore, studies usually test for a limited number of potential factors.

This chapter examines a long list of variables that may influence the choice for IT; these factors fall into the categories: macroeconomic, fiscal, external, financial, and institutional. While macroeconomic, external, and fiscal factors leading to IT adoption have been discussed in the literature, financial system and institutional characteristics have received little attention. The study uses data for 60 countries over the period 1985–2008. Apart from analyzing the full sample, we also investigate OECD and non-OECD countries separately in order to control for possible heterogeneity and institutional differences. Additionally, we test whether factors differ across various types of IT.

Also from a methodological perspective, this study distinguishes itself from previous research as we focus exclusively on the factors leading to IT adoption and ignore all observations after the adoption. Other studies retain observations for IT countries after the adoption, thereby estimating simultaneously the factors of adoption and continuation of IT. This may lead to inadequate statistical inference and endogeneity problems.

We find that macroeconomic, fiscal, and financial factors significantly affect the likelihood of adoption of IT. The factors leading to IT adoption differ between OECD and non-OECD countries and between soft and full-fledged inflation targeters. These differences come from different economic characteristics of countries and the credibility of their central banks.

The remainder of this chapter is organized as follows. Section 3.2 reviews the literature and describes the analyzed factors. Sections 3.3 and 3.4 describe the methodology and data, respectively. Section 3.5 presents the main results, while section 3.6 offers a sensitivity analysis. Section 3.7 concludes.

## 3.2 Literature review

Previous empirical studies have examined a number of potential factors influencing the choice of IT. Below, we provide a summary of their findings.

Inflation is a primary concern of monetary policy, which is why it is analyzed in all the studies on IT choice. Previous research provides mixed results. While Mishkin and Schmidt-Hebbel (2001), Mukherjee and Singer (2008), and Gonçalves and Carvalho (2009) find a positive impact of inflation on the likelihood to adopt IT, Hu (2006), Lin and Ye (2007, 2009), Lucotte (2010), and De Mendonça and de Guimarães e Souza (2012) report a negative effect of inflation. Vega and Winkelried (2005) also include inflation volatility and find that it is negatively associated with IT choice.

Apart from inflation, several studies examine the effects of macroeconomic performance on IT choice by adding such variables as investment (Vega and Winkelried, 2005), GDP growth and its variability (Hu, 2006; Mukherjee and Singer, 2008), and income growth (Lin and Ye, 2007, 2009). Studies find that investment and GDP growth variability have a significant positive effect on the choice of IT. Additionally, Leyva (2008), Mukherjee and Singer (2008), Lucotte (2010), and De Mendonça and de Guimarães e Souza (2012) include GDP per capita to control for differences in income levels between countries. They find that countries with higher levels of GDP per capita are more likely to adopt IT.

Another factor studied in the literature is the exchange rate regime. The adoption of IT is associated with flexible exchange rates to avoid a conflict between the exchange rate target and the inflation target. Several studies (Hu, 2006; Lin and Ye, 2007, 2009; Mukherjee and Singer, 2008; Lucotte, 2010) report that countries with a floating exchange rate regime are more likely to adopt IT. Additionally, Mukherjee and Singer (2008) find that exchange rate variability is positively associated with IT adoption, while Mishkin and

Schmidt-Hebbel (2001) obtain a similar result for exchange rate bandwidth.

Previous studies also analyze the effects of fiscal discipline (measured by government debt or fiscal balance) on IT adoption, as it is relevant for maintaining price stability. Vega and Winkelried (2005), Hu (2006), Gonçalves and Carvalho (2009), and Lucotte (2010) report that fiscal discipline is positively associated with the probability of having IT, whereas Mishkin and Schmidt-Hebbel (2001), Lin and Ye (2007, 2009) find that this factor is insignificant.

Several studies include trade openness and come to mixed conclusions. Whereas Gerlach (1999), Vega and Winkelried (2005), Lin and Ye (2009), and De Mendonça and de Guimarães e Souza (2012) find that less open economies are more likely to choose IT, Mishkin and Schmidt-Hebbel (2001), Leyva (2008), and Lucotte (2010) report opposite results. Hu (2006) adds external debt as a proxy for financial openness; however, it is found insignificant.

Financial factors have received little attention in the literature. Hu (2006) finds that financial depth, measured as the ratio of M2 to GDP, increases the probability of having IT. Leyva (2008) finds that countries with developed financial systems are more likely to adopt IT, while Lucotte (2010) reports opposite results for emerging and developing countries.

Finally, previous studies include institutional factors leading to IT adoption. Hu (2006), Lin and Ye (2007, 2009), and Lucotte (2010) find that higher central bank independence increases the likelihood of having IT, as an independent central bank is resistant to government pressures and more committed to achieving price stability. However, Gerlach (1999) reports that central banks become more independent after they adopt IT. Mishkin and Schmidt-Hebbel (2001) distinguish different dimensions of independence and conclude that higher instrument and lower goal independence of central banks increase the probability of having IT. Apart from monetary institutions, two studies (Mukherjee and Singer, 2008; Lucotte, 2010) analyze the impact of political institutions on IT choice.

This chapter analyzes several factors already mentioned in the literature and adds some new ones. Most importantly, we include a group of financial factors, namely financial stability, development, and structure. These aspects (except for development) have not been examined before in the context of IT adoption. As financial system characteristics and stability have become increasingly relevant for monetary policy conduct, they may have a significant impact on the choice of monetary strategy and, in particular, on the decision to adopt IT.

### 3.2.1 Macroeconomic factors

#### Inflation

Several authors argue that countries choose IT in order to achieve low inflation; hence, economies with higher prior inflation are more likely to adopt this strategy (Svensson, 1997; Freedman, 2001; Mishkin and Schmidt-Hebbel, 2001; Gonçalves and Carvalho, 2009). However, many inflation targeters adopted the strategy after inflation had come down, so that it may also be argued that low inflation is a factor leading to IT adoption (Carare et al., 2002). We expect that low inflation increases the likelihood to adopt IT. There is a potential endogeneity problem with inflation. Inflation before IT adoption could be low because of the expectation that inflation will fall as a result of IT implementation. We deal with this problem by using the sample for the pre-adoption period only and including the one-year lag of the explanatory variables (see section 3.3 for details).

#### Output growth and volatility

We include output growth and volatility to control for the macroeconomic performance of countries. Economic growth could affect central banks' decisions to adopt IT. Additionally, countries with increasing economic volatility are motivated to adopt IT in order to stabilize output (Svensson, 1999; Mukherjee and Singer, 2008). Batini and Laxton (2006) note that many emerging countries experienced high macroeconomic volatility before the adoption of IT. Thus, we expect that low output growth and high output volatility increase the likelihood to adopt IT.

#### Exchange rate regime and volatility

IT requires a flexible exchange rate regime because an exchange rate target may lead to a conflict between the objectives of low inflation and a stable exchange rate (Fischer, 2001; Mishkin and Savastano, 2001; Mishkin, 2004). However, several emerging and developing countries initially adopted a soft version of IT while still using crawling exchange rate bands.[1] Once these countries completed disinflation, they abandoned exchange rate bands and switched to full-fledged IT. Meanwhile, advanced countries started to target inflation as a single anchor after the abandonment of exchange rate pegs and the ERM (Bernanke et al., 1999; Freedman and Laxton, 2009). Therefore, we expect that a flexible exchange rate regime and high exchange rate volatility influence the likelihood to adopt IT positively.

### 3.2.2 Fiscal factors

Fiscal discipline is often considered as a factor leading to IT adoption (Amato and Gerlach, 2002; Carare et al., 2002; Mishkin, 2004; Batini and Laxton, 2006). Unsustainable fiscal policy may force the central bank to finance fiscal deficits at the cost of higher inflation, jeopardizing the credibility of the central bank. In addition, a highly indebted country may aim for higher inflation in order to reduce the real value of its debt. Thus, a country that wants to adopt IT should have its public finances in order. We expect that low budget deficits and low public debt increase the likelihood to adopt IT.

### 3.2.3 External factors

#### Openness of the economy

The literature identifies openness of the economy as a relevant factor for monetary policy choice (Fatás et al., 2004; Batini and Laxton, 2006). Small open economies are dependent on foreign trade and exposed to external real shocks. As such countries are sensitive to exchange rate and commodity

[1] Countries that initially adopted IT combined with exchange rate pegs are: Chile, Colombia, Israel, Mexico, Peru, and Turkey.

price changes, they tend to limit exchange rate movements. Consequently, open economies often prefer to have exchange rate pegs rather than IT with flexible exchange rates. Nevertheless, as Svensson (2000) argues, open economies can still successfully implement IT if the reaction function of the central bank is modified to include exchange rate changes, while preserving the inflation objective. We expect that openness of the economy has a positive impact on the probability of adopting IT.

**External exposure**

Several authors mention external exposure as a factor influencing the decision to adopt IT, especially by emerging and developing countries (Carare et al., 2002; Mishkin, 2004). External exposure is defined as the dependence of countries on external financing through foreign capital and credit (Milesi-Ferretti and Razin, 1998). Sudden reversals of capital flows in countries with high external exposure lead to liquidity constraints of borrowers, large currency depreciations, and subsequently cause currency crises (Kaminsky et al., 1998; Milesi-Ferretti and Razin, 1998). Under these circumstances, countries prefer to focus on exchange rate stability by using exchange rate pegs. Thus, external exposure is expected to have a negative effect on the likelihood of IT adoption.

### 3.2.4 Financial factors

**Financial stability**

Schinasi (2004) broadly defines financial stability as the ability of the financial system to facilitate an efficient allocation of resources in the economy; to assess and manage financial risks; and to perform its main functions through self-corrective mechanisms even when affected by external shocks or financial imbalances. According to Carare et al. (2002), Truman (2003), Mishkin (2004), and Roger (2009), weak and unstable financial institutions may create circumstances under which the central bank cannot raise interest rates to sustain the inflation target because it may cause the collapse of the fragile banking sector and, subsequently, lead to a financial crisis. In addition, weak financial institutions may turn for liquidity injections to the central bank which leads to escalating inflation. In both situations, IT may fail and the credibility of the central bank may be undermined. Therefore, we expect that financial instability (defined as the presence of financial crises) decreases the likelihood to adopt IT.

**Financial system development**

A well-developed financial system with liquid and active financial markets may facilitate IT (Carare et al., 2002; Truman, 2003; Batini and Laxton, 2006). Well-functioning financial markets absorb short-term financial shocks, minimizing their impact on the real economy. In addition, a well-developed financial system provides more opportunities for resource allocation and reduces the risk that funding dries up. Consequently, a central bank has to care less about financial stability and can focus on inflation control. Therefore, countries with developed financial systems are expected to be more likely to adopt IT.

**Financial structure**

A distinction can be made between market-based and bank-based financial systems (Demirgüç-Kunt and Levine, 2001). In a bank-based system, the banking sector dominates in financing the real economy, whereas in a market-based system the stock and bond markets are more important for intermediation. Chowdhury et al. (2006) and Kwapil and Scharler (2010) find that countries with a market-based financial system have a higher interest rate pass-through than countries with a bank-based system. To ensure a strong response of inflation expectations to monetary policy decisions, IT requires effective monetary policy transmission channels. We expect that countries with market-based financial systems are more likely to adopt IT.

### 3.2.5 Institutional factors

Several authors emphasize central bank independence as an important institutional feature of IT (Gerlach, 1999; Amato and Gerlach, 2002; Carare et al., 2002; Truman, 2003; Mishkin, 2004; Batini and Laxton, 2006; Roger, 2009). What matters most is instrument independence, i.e. the central bank is independent from the government in choosing instruments to achieve its goals. Similar to inflation, an important issue is whether countries should have an independent central bank before adopting IT or whether they grant instrument independence to their central bank after they adopt this strategy. Mishkin and Schmidt-Hebbel (2001) find that instrument-independent central banks are more likely to adopt IT. Thus, higher instrument independence of a central bank is expected to increase the likelihood to adopt IT.

All the analyzed factors, their expected signs, and variables used to test them are summarized in Table B.1 in the Annex.

## 3.3 Methodology

During each year, a country chooses either to adopt IT or to continue implementing an alternative, non-IT strategy. We employ a panel binary model where the dependent variable $y_{it}$ is a dummy that takes the value 1 if country $i$ adopts IT in year $t$ , and 0 otherwise.

In the presence of unobserved characteristics, the appropriate specification is a panel probit model with random effects that is estimated using Maximum Likelihood. The estimation of a fixed effects model faces the incidental parameters problem (Wooldridge, 2002), as the number of parameters to be estimated increases with the number of countries in the sample. However, there is no fixed effects probit estimator that can deal with this problem. Although fixed effects logit solves the incidental parameters problem, it drops all observations for countries that did not change monetary strategy in the analyzed period, i.e. observations for which $n_i = \sum_{t=1}^{T} y_{it} = 0$ are excluded from the log-likelihood function (Wooldridge, 2002, p. 491). Therefore, we do not estimate a fixed effects model.

The underlying latent model has the general structure:

$$y^*_{it} = \alpha + \boldsymbol{\beta}'\boldsymbol{MAC}_{i,t-1} + \boldsymbol{\gamma}'\boldsymbol{FIS}_{i,t-1} + \boldsymbol{\theta}'\boldsymbol{EXT}_{i,t-1} + \boldsymbol{\kappa}'\boldsymbol{FIN}_{i,t-1} + \boldsymbol{\delta}'\boldsymbol{INS}_{i,t-1} + \mu_i + \varepsilon_{it}, \qquad i = 1,\ldots,N;\; t = 1,\ldots,T_i, \tag{3.1}$$

where $y^*_{it}$ is an unobserved latent variable which describes the decision to adopt IT, $y_{it} = 1$ if $y^*_{it} > 0$ and $y_{it} = 0$ if $y^*_{it} \leq 0$; $T_i$ is the year of IT adoption for those countries that adopted IT, and the last year in the sample (i.e. 2008) for countries that did not adopt IT during the analyzed period; $\alpha$ is a constant term; $\boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\theta}, \boldsymbol{\kappa}, \boldsymbol{\delta}$ are vectors of parameter estimates; $\mu_i$ is an unobserved random effect, uncorrelated with explanatory variables; $\varepsilon_{it}$ is a normally, independently, and identically distributed error term with mean 0 and variance 1; and $\boldsymbol{X}_{i,t-1} \equiv [\boldsymbol{MAC}_{i,t-1}, \boldsymbol{FIS}_{i,t-1}, \boldsymbol{EXT}_{i,t-1}, \boldsymbol{FIN}_{i,t-1}, \boldsymbol{INS}_{i,t-1}]$ are explanatory variables. Following previous studies, we include the explanatory variables with a one-year lag to avoid potential endogeneity.[2]

The probability to adopt IT is formulated as:

$$\Pr(y_{it} = 1|\boldsymbol{X}_{i,t-1}, \mu_i) = \Phi[\alpha + \boldsymbol{\beta}'\boldsymbol{MAC}_{i,t-1} + \boldsymbol{\gamma}'\boldsymbol{FIS}_{i,t-1} + \boldsymbol{\theta}'\boldsymbol{EXT}_{i,t-1} + \boldsymbol{\kappa}'\boldsymbol{FIN}_{i,t-1} + \boldsymbol{\delta}'\boldsymbol{INS}_{i,t-1} + \mu_i], \tag{3.2}$$

where $\Phi(.)$ is a cumulative distribution function of the standard normal distribution.

The explanatory variables are classified into five groups: (1) macroeconomic factors ($\boldsymbol{MAC}_{i,t-1}$): inflation, output growth and volatility, flexible exchange rate regime, and exchange rate volatility; (2) fiscal factors ($\boldsymbol{FIS}_{i,t-1}$): fiscal balance and government debt; (3) external factors ($\boldsymbol{EXT}_{i,t-1}$): openness of the economy and external exposure; (4) financial factors ($\boldsymbol{FIN}_{i,t-1}$): financial instability, financial structure, and financial development; and (5) institutional factor ($\boldsymbol{INS}_{i,t-1}$): central bank instrument independence.

The decision to adopt IT is based on information available to the cent-

[2] In this paper, we do not study the impact of forward-looking variables, such as inflation and exchange rate expectations, because of the lack of data.

ral bank at the moment of decision making. What happens afterwards is not relevant for the decision to adopt IT and, therefore, we do not keep these observations. In fact, using explanatory variables that refer to the post-adoption period may lead to reverse causality and endogeneity problems. For example, inflation in year $(t-1)$ could influence the decision to change to IT in year $t$. However, inflation in year $(t+1)$ will be influenced by IT practice. To avoid endogeneity and focus exclusively on IT adoption, we only retain observations for the pre-adoption period and the first year of IT adoption for the IT countries in the sample.

## 3.4 Data description

We use data of 60 countries over the period 1985–2008.[3] 30 countries in our sample (17 OECD and 13 non-OECD countries) have adopted IT during this period (inflation targeters), and 30 other countries did not adopt it (non-inflation targeters). To make the two groups comparable and reduce the risk of selection bias, we include in the group of non-inflation targeters also OECD and non-OECD countries. The OECD part of this group consists of 13 OECD non-inflation targeters. Following the approach of Rose (2007) and Lin and Ye (2009), we include in the non-OECD part 17 emerging and developing countries with GDP per capita that is at least as high as GDP per capita of the poorest non-OECD inflation targeter.[4]

Table 3.1 lists the countries in our sample and shows the dates of IT adoption. There is disagreement in the literature over the precise dates of adoption, since different criteria are used for pinpointing the switch to IT. Bernanke et al. (1999) associate the start of IT with the public announcement of the first inflation target, and Ball and Sheridan (2004) with the implementation of the first target. Batini and Laxton (2006) consider central banks as inflation targeters if they use an inflation target as the single nom-

[3] IT was adopted for the first time in 1989 in New Zealand. The sample period therefore starts in 1985. We do not include the years of and after the recent financial crisis (2008–2010), as from these years central banks began adding the objective of financial stability.

[4] We include only those countries for which the data are available in the analyzed period.

Table 3.1. **List of countries with dates of IT adoption**

| **IT countries** | | | | | | | |
|---|---|---|---|---|---|---|---|
| OECD (17) | | | | Non-OECD (13) | | | |
| Country | Official adoption | SIT dates | FFIT dates | Country | Official adoption | SIT dates | FFIT dates |
| Australia | 1993 | 1993 | 1994 | Armenia[a] | 2006 | 2006 | n/a |
| Canada | 1991 | 1991 | 1994 | Brazil | 1999 | - | - |
| Czech Republic | 1998 | - | - | Chile | 1991 | 1991 | 1999 |
| Finland[b] | 1993 | - | - | Colombia | 2000 | 1995 | 2000 |
| Hungary | 2001 | - | - | Ghana | 2007 | - | - |
| Iceland | 2001 | - | - | Guatemala | 2005 | - | - |
| Mexico | 2001 | 1995 | 2001 | Indonesia | 2005 | - | - |
| New Zealand | 1990 | 1990 | 1991 | Israel | 1992 | 1992 | 1997 |
| Norway | 2001 | - | - | Peru | 2002 | 1994 | 2002 |
| Poland | 1999 | - | - | Philippines | 2002 | 1995 | 2002 |
| Slovakia[b] | 2005 | - | - | Romania | 2005 | - | - |
| South Korea | 1998 | 1998 | 2001 | South Africa | 2000 | - | - |
| Spain[b] | 1995 | 1994 | 1995 | Thailand | 2000 | - | - |
| Sweden | 1993 | - | - | | | | |
| Switzerland | 2000 | - | - | | | | |
| Turkey | 2006 | 2002 | 2006 | | | | |
| United Kingdom | 1993 | - | - | | | | |

| **Non-IT countries** | | | | | |
|---|---|---|---|---|---|
| OECD (13) | | | Non-OECD (17) | | |
| Austria | Greece | Luxemburg | Argentina | Egypt | Pakistan |
| Belgium | Ireland | Netherlands | Bolivia | Estonia | Panama |
| Denmark | Italy | Portugal | Bulgaria | India | Singapore |
| France | Japan | United States | China | Latvia | Sudan |
| Germany | | | Costa Rica | Lithuania | Venezuela |
| | | | Cyprus | Malaysia | |

*Notes:* Official adoption dates are based on central banks' documents. The alternative dates refer to the start of SIT and FFIT, respectively. Following Hu (2006) and Lucotte (2010), we apply the 'half-year rule' — if IT is adopted in the second half of year $t$, the adoption year is $(t+1)$, otherwise the adoption year is $t$.

[a] Armenia is still officially in transition to FFIT.

[b] Finland and Spain abandoned IT in 1999 because of the adoption of the euro; same holds for Slovakia in 2009.

Sources: Mishkin and Schmidt-Hebbel (2001), Truman (2003), Fatás et al. (2004), Vega and Winkelried (2005), Leyva (2008), Freedman and Laxton (2009), Roger (2009), and central banks' publications.

inal anchor for monetary policy. Mishkin and Schmidt-Hebbel (2001), Vega and Winkelried (2005), and Freedman and Laxton (2009) suggest that central banks may choose one of the two forms of the strategy — soft or full-fledged IT — depending on their commitment and policy objectives. Soft inflation targeting (SIT) involves the simple announcement of an inflation target, not accompanied by a strong institutional commitment, and coexistence of the inflation target with other nominal anchors (e.g., money growth targets or exchange rate pegs). This description applies mostly to emerging and developing countries, which often adopted IT but initially kept exchange rate pegs in place. Full-fledged inflation targeting (FFIT) involves using the inflation target as the single nominal anchor for monetary policy and requires strong commitment to the target.

Table 3.1 shows three dates for the start of IT: the start according to the central bank, and dates for the start of SIT and FFIT. While SIT and FFIT adoption dates for OECD countries tend to coincide, there are substantial differences between SIT and FFIT dates for six non-OECD countries, and for Mexico and Turkey. In our main analysis, we use all three dates: official adoption dates as well as SIT and FFIT dates to check whether the factors leading to adoption are different between the two versions of IT.

Another issue is whether Switzerland should be classified as an inflation targeter. While Mishkin and Schmidt-Hebbel (2001), Fatás et al. (2004), and Vega and Winkelried (2005) classify Switzerland as a de facto inflation targeter, Truman (2003) and Roger (2009) do not include it in their sample of IT countries. The Swiss National Bank does not consider itself an inflation targeter. However, it uses inflation forecasts as a main indicator of monetary policy aimed to achieve price stability in the medium and long run. Thus, in our main analysis, we include Switzerland as an inflation targeter; in the sensitivity analysis, we exclude it from this group.

Table B.1 (Annex) offers a detailed description of the variables used and their data sources. To reduce the impact of extreme inflation observations, the inflation rate is transformed as $\frac{\pi/100}{1+\pi/100}$. To proxy output growth and volatility we use annual GDP growth rates and the annual standard deviation of monthly Industrial Production growth rates, respectively. The flexible exchange rate regime dummy is based on the de facto classification of Levy-Yeyati and Sturzenegger (2005) and takes the value 1 if a country has a floating exchange rate regime, and 0 otherwise. Exchange rate volatility is measured by the annual standard deviation of monthly changes of the real effective exchange rate (REER).

The fiscal factors included are general government fiscal balance and central government debt, both expressed as percentage of GDP. Openness is measured as the sum of exports and imports as share of GDP. Following Kaminsky et al. (1998) and Milesi-Ferretti and Razin (1998), we measure external exposure by external debt as percentage of GDP.

A financial crisis dummy is used as a proxy for financial instability. It takes the value 1 if a country experiences a sovereign debt, currency, or banking crisis in a given year, and 0 otherwise. The data on financial crises come from Honahan and Laeven (2005) and Laeven and Valencia (2008). Following Levine et al. (2000) and Beck et al. (2009), we use private credit to GDP as a proxy for financial development. The methodology for constructing a market-based financial structure dummy is based on Demirgüç-Kunt and Levine (2001) and Beck and Levine (2002).[5]

The final variable is central bank instrument independence. As a proxy, we use a dummy for economic independence of the central bank, which takes the value 1 if the central bank is economically independent, and 0 otherwise. The dummy values are based on indices constructed in the literature (Cukierman et al., 1992; Cukierman et al., 2002; Arnone et al., 2007). Since most studies measure independence as an average index over a cer-

[5] To create a market-based financial structure dummy, we first construct the aggregate financial structure index. The aggregate structure index consists of the size, activity, and efficiency sub-indices, which measure the size, activity, and efficiency of the financial system, respectively. They are calculated as follows:
Size Index = stock market capitalization/domestic assets of deposit money banks;
Activity Index = total stock market value traded/private credit of deposit money banks;
Efficiency Index = (total stock market value traded/GDP)$\times$ overhead costs.
The aggregate structure index is the average of these three sub-indices. If the structure index is above the mean for the full sample, a country has a market-based financial system, and if it is below the mean, it has a bank-based system.

tain period of time, we use central banks' documents to indicate the exact year when central bank independence was enhanced.

To check for potential multicollinearity between the variables, we perform a correlation analysis (see Table B.2 in the Annex). Most explanatory variables are not highly and significantly correlated.

Table 3.2 presents the mean comparison tests of the explanatory variables for all countries and for subsamples of OECD and non-OECD countries. We compare the means of variables in two groups — inflation targeters and non-inflation targeters. We employ a two-sided mean comparison t test, where the null hypothesis is that the mean difference of two groups is zero: $H_0$: *mean (inflation targeters) – mean (non-inflation targeters)* $= 0$. The alternative hypothesis states that the mean difference is not zero. We perform the mean comparison tests for unequal variances of variables in two groups.

The table suggests that there are important differences between both groups of countries, as the mean values differ significantly for all variables. Prior to the adoption of IT, inflation targeters had on average higher inflation, lower levels of output growth and volatility, and higher exchange rate volatility than non-inflation targeters. In addition, inflation targeters had more flexible exchange rate regimes, a better fiscal performance, and lower openness. Surprisingly, prior to the adoption central banks in IT countries had lower instrument independence than central banks in non-IT countries. This suggests that inflation targeters made their central banks independent after they adopted IT.

The mean comparison tests of the financial variables suggest that inflation targeters more frequently experienced financial crises prior to IT adoption and have less developed financial markets than non-inflation targeters. In addition, inflation targeters more often have a market-based financial system than non-inflation targeters.

The mean comparison tests for OECD countries show that the mean differences between inflation targeters and non-inflation targeters are statistically significant for all variables, except output growth. For the non-OECD sample, inflation targeters and non-inflation targeters do not differ signific-

Table 3.2. **Descriptive statistics — mean comparison tests**

| Variable | All countries | | | OECD countries | | | Non-OECD countries | | |
|---|---|---|---|---|---|---|---|---|---|
| | IT | Non-IT | P-value | IT | Non-IT | P-value | IT | Non-IT | P-value |
| Inflation | 0.16 | 0.07 | 0.00 | 0.12 | 0.03 | 0.00 | 0.20 | 0.11 | 0.00 |
| Output growth | 3.23 | 4.03 | 0.00 | 2.66 | 2.84 | 0.52 | 3.82 | 5.10 | 0.00 |
| Output volatility | 9.41 | 11.14 | 0.00 | 10.32 | 12.65 | 0.00 | 8.11 | 9.26 | 0.00 |
| Flexible exchange rate regime | 0.37 | 0.19 | 0.00 | 0.32 | 0.22 | 0.01 | 0.41 | 0.17 | 0.00 |
| Exchange rate volatility | 2.60 | 1.54 | 0.00 | 2.13 | 0.94 | 0.00 | 3.08 | 2.08 | 0.00 |
| Fiscal balance | -1.86 | -2.32 | 0.06 | -1.96 | -2.97 | 0.01 | -1.76 | -1.67 | 0.80 |
| Government debt | 40.41 | 59.36 | 0.00 | 33.68 | 61.19 | 0.00 | 48.69 | 57.59 | 0.03 |
| Trade openness | 60.65 | 92.47 | 0.00 | 64.76 | 86.19 | 0.00 | 56.36 | 98.14 | 0.00 |
| External debt | 53.49 | 77.53 | 0.00 | 56.79 | 112.19 | 0.00 | 50.51 | 51.78 | 0.63 |
| Financial instability | 0.31 | 0.21 | 0.00 | 0.25 | 0.15 | 0.01 | 0.36 | 0.26 | 0.01 |
| Market-based financial structure | 0.50 | 0.28 | 0.00 | 0.50 | 0.29 | 0.00 | 0.50 | 0.28 | 0.00 |
| Financial development | 0.50 | 0.73 | 0.00 | 0.62 | 0.98 | 0.00 | 0.36 | 0.52 | 0.00 |
| Central bank instrument independence | 0.33 | 0.47 | 0.00 | 0.34 | 0.64 | 0.00 | 0.32 | 0.30 | 0.62 |

*Notes:* The table reports means of explanatory variables in IT and non-IT country groups for the full sample, and for OECD and non-OECD samples. For IT countries, the statistics are calculated using the pre-adoption period from 1985 until the official adoption date. For non-IT countries, the period is 1985–2008. P-value$<$ 0.05 indicates the rejection of the null hypothesis and suggests that the mean difference of a particular variable is statistically significant.

antly in terms of central bank instrument independence, external debt, and fiscal balance.

## 3.5 Empirical results

Before carrying out model estimations, we apply panel unit-root tests to check for stationarity of the explanatory variables (see Table B.3 in the Annex). We use Fisher-type tests which allow for unbalanced panels. Only two variables turn out to be non-stationary in either ADF or PP test. This should not cause any serious problems during the estimation.

Table 3.3 presents the estimation results for the full sample. We find no evidence for the existence of unobserved cross-country heterogeneity since random effects are insignificant in the model. Consequently, we estimate a pooled probit model with robust (White-corrected) standard errors. Since coefficient estimates in probit cannot be interpreted directly, we report average marginal effects.[6] Column (1) shows the estimation results for official dates of adoption; columns (2) and (3) — for SIT and FFIT dates, respectively.

The results using official adoption dates suggest that the likelihood that a country adopts IT is significantly associated with the country's macroeconomic performance, its exchange rate arrangements, fiscal discipline, and financial development.

There is strong evidence that countries with low inflation are more likely to adopt IT. Thus, countries adopt IT when they have already achieved low and stable inflation. The marginal effect of inflation is much higher than that of other factors, indicating the high relevance of this variable for IT choice.[7]

GDP growth is insignificant with a negative sign, while output volatility is significant with a positive sign. Thus, countries with higher output

[6] Average marginal effects are computed as averages of individual marginal effects. The standard errors of marginal effects are calculated using the delta method.

[7] Note that if we compare coefficient estimates instead of marginal effects, the coefficient estimate of inflation is also much higher (in absolute sense) than the coefficients of other variables. This holds for all estimated models in the main and sensitivity analysis. Results with reported coefficient estimates are available on request.

volatility are more likely to adopt IT.

Next, we find that a country with a flexible exchange rate regime is more likely to adopt IT. According to the size of the marginal effect, this variable is the second most relevant for the decision to adopt IT. Exchange rate volatility is significant with a positive sign indicating that countries with more volatile exchange rates tend to choose IT.

Our findings indicate that lower government debt significantly increases the probability to adopt IT. However, the marginal effect of the fiscal balance is insignificant. The external factors – the openness of the economy and external exposure — do not affect the likelihood to adopt IT.

Also our proxy for financial instability is insignificant. Interestingly, financial development is significant with a negative sign. This result suggests that countries with less developed financial systems are more likely to adopt IT. In fact, it may be the case that countries with underdeveloped financial systems choose to implement IT as a way to control inflation and also to develop their financial system.

The financial structure index has a positive sign, which implies that countries with a market-based financial system are more likely to adopt IT. However, the marginal effect is insignificant.

Our proxy for central bank instrument independence is insignificant with a positive sign. As suggested in section 3.2, it is possible that the central bank becomes independent after IT is adopted. In addition, this result may be caused by the fact that — at this stage — we do not distinguish between advanced and emerging and developing countries. The quality of institutions in advanced countries may be better than in emerging and developing countries. Thus, while there is no evidence that central bank instrument independence affects the choice for IT in the full sample, this may be different for the subsample of emerging and developing countries.

Next, the alternative dates of adoption as shown in Table 3.1 are used, indicating the start of SIT (column (2) of Table 3.3) and FFIT (column (3) of Table 3.3). The findings suggest that the factors leading to both types of IT differ slightly. Most notably, inflation is less important for adopting SIT than

Table 3.3. **Factors leading to IT adoption — main results**

| | (1) Official IT dates | | (2) SIT dates | | (3) FFIT dates | |
|---|---|---|---|---|---|---|
| Inflation | −0.471 | *** | −0.218 | ** | −0.432 | *** |
| | (0.170) | | (0.103) | | (0.137) | |
| Output growth | −0.003 | | −0.003 | | −0.005 | ** |
| | (0.003) | | (0.003) | | (0.002) | |
| Output volatility | 0.002 | * | 0.002 | * | 0.002 | |
| | (0.001) | | (0.001) | | (0.001) | |
| Flexible exchange rate regime | 0.065 | *** | 0.064 | *** | 0.058 | *** |
| | (0.019) | | (0.020) | | (0.019) | |
| Exchange rate volatility | 0.012 | ** | 0.014 | *** | 0.006 | |
| | (0.005) | | (0.005) | | (0.004) | |
| Fiscal balance | 0.002 | | 0.002 | | 0.003 | |
| | (0.004) | | (0.004) | | (0.003) | |
| Government debt | −0.001 | ** | −0.001 | ** | −0.001 | ** |
| | (0.0005) | | (0.0004) | | (0.0004) | |
| Trade openness | 0.000 | | 0.000 | | 0.000 | |
| | (0.0002) | | (0.0002) | | (0.0002) | |
| External debt | −0.0001 | | −0.0001 | | −0.0001 | |
| | (0.0002) | | (0.0002) | | (0.0001) | |
| Financial instability | −0.002 | | −0.002 | | 0.002 | |
| | (0.019) | | (0.019) | | (0.020) | |
| Market-based financial structure | 0.021 | | 0.039 | * | 0.019 | |
| | (0.019) | | (0.021) | | (0.018) | |
| Financial development | −0.052 | *** | −0.052 | *** | −0.048 | ** |
| | (0.020) | | (0.020) | | (0.019) | |
| Central bank | 0.007 | | 0.028 | | 0.000 | |
| instrument independence | (0.019) | | (0.022) | | (0.019) | |
| Number of observations | 562 | | 531 | | 577 | |
| Log-likelihood | −88.11 | | −86.47 | | −88.46 | |
| Pseudo $R^2$ | 0.16 | | 0.17 | | 0.14 | |
| Wald $\chi^2$ | 29.01 | *** | 30.03 | *** | 25.15 | ** |

*Notes:* The table reports average marginal effects and their robust standard errors (in parentheses). ***, **, and * indicate the significance at the 1%, 5%, and 10% significance level, respectively. Wald $\chi^2$ test, equivalent to the F test in linear regression, evaluates the goodness-of-fit of the model.

for adopting FFIT. Apparently, countries may adopt SIT without much concern for low inflation, since central banks do not strongly commit to reaching the inflation target. However, the decision to switch to FFIT requires sufficiently low inflation.[8] As for other factors, countries with high output and exchange rate volatility, a flexible exchange rate regime, and better fiscal discipline are more likely to adopt SIT. Financial structure and development play a significant role, too. The choice of FFIT is not related to financial structure and output volatility, but other factors have a similar impact as in the model for the likelihood to adopt SIT. In addition, output growth is significant with a negative sign for FFIT adoption.

Following Lucotte (2010), to control for the 'popularity effect' of IT, we add an explanatory variable that counts the number of countries that have adopted IT until year $t$. Countries may adopt IT after observing that others chose this strategy as well. The inclusion of this variable does not change our main conclusions; the 'popularity effect' is insignificant with a positive sign for official IT and SIT adoption dates, while it is significant for FFIT dates. These estimation results are available in Samarina and de Haan (2014).

## 3.6 Sensitivity analysis

We conduct an extensive sensitivity analysis to check the robustness of our findings to changing and adding explanatory variables, modifying the country sample, and distinguishing several sub-samples. In the robustness checks we use official dates of IT adoption.[9]

First, we include several additional explanatory variables that have been suggested in the literature to correct for a potential omitted variable bias. Following Carare and Stone (2006) and Lucotte (2010), we include the level

[8] For example, Chile adopted SIT in 1991 when the country had high inflation. After inflation was brought down from 21.8% in 1991 to 3.3% in 1999, Chile switched to FFIT.

[9] Several sensitivity tests are not reported but are available on request. We use different specifications of volatility and exchange rate regime. Also, there is a potential multicollinearity problem for openness, exchange rate regime and exchange rate volatility. We include in the estimation each of these variables separately and in combinations with others. We find that our main results are robust to different specifications.

of economic development — proxied by the log of real GDP per capita — as a factor leading to IT adoption. According to Lucotte (2010), more developed countries have better conditions for IT. Next, we include financial openness as another external factor. Higher capital mobility may shift the central bank's focus from inflation to exchange rates, making IT a less preferred strategy option. We use the Chinn-Ito index to proxy financial openness (Chinn and Ito, 2008). The inclusion of these additional variables does not substantially change our main results. The economic development proxy is insignificant, while the coefficient estimate of the financial openness index is significant and negative.[10] This implies that financially open countries are less likely to adopt IT.

As a second robustness check, we drop all observations for EMU countries after the start of the currency area. By joining the euro area, these countries gave up their national sovereignty and delegated monetary policy to the ECB. Since the ECB is responsible for monetary policy in the euro area, EMU countries do not choose a monetary strategy. The results as shown in column (1) of Table 3.4 are quite similar to those reported in Table 3.3.

We also re-estimate the models after including Switzerland as a non-inflation targeter. This modification does not change our main conclusions.

Our next robustness check focuses on distinguishing different types of IT. In the main analysis we estimated factors of IT adoption separately for SIT and FFIT dates, but assumed that IT adoption is a binary choice (adopt IT or not). However, it is reasonable to include several types of IT in one model and examine the factors leading to the adoption of each IT type as well as factors influencing transition from one IT type to another. Following the approach of O'Sullivan and Tomljanovich (2012), we construct an IT index which we use for one of the dimensions proposed by the authors, namely the co-existence of other nominal targets in monetary policy. We consider this aspect most relevant and obvious for distinguishing different types of IT. The new dependent variable takes values 0, 1, or 2, depending on which monetary strategy a country chooses. Value 0 corresponds to

[10] The results of these two robustness checks are available on request.

a non-IT strategy, 1 to IT with more than one nominal target, and 2 to IT with a single, inflation target.[11] These choices are mutually exclusive and unordered. The suitable specification is a multinomial probit model with alternative-invariant regressors, estimated by Maximum Likelihood.[12] The probability that country $i$ chooses monetary policy strategy $j$ in year $t$, conditional on the set of factors $\boldsymbol{X}_{i,t-1}$ is:

$$p_{ijt} = \Pr(y_{it} = j) = \Phi(\boldsymbol{X}_{i,t-1}\boldsymbol{\psi}), \;\; i = 1, \ldots, N; \; t = 1, \ldots, T; \; j = 0, 1, 2. \quad (3.3)$$

For normalization, the non-IT strategy is set as the base, since it is most prominent. The results are presented in Table 3.5. We report marginal effects of a change in regressors on the probability of choosing strategy $j$.

Our findings suggest substantial differences in the factors leading to the choice of IT types. First, low inflation significantly increases the probability of adopting IT with a single, inflation target, while for the choice of IT with multiple targets this factor is insignificant. Countries that do not have sufficiently low inflation often start practicing IT with a combination of inflation targets and other nominal anchors. Second, external factors, such as higher exchange rate volatility and lower external exposure, significantly increase the probability of adopting IT with multiple nominal anchors. Apparently, countries that are sensitive to exchange rate changes adopt IT with multiple targets (e.g., exchange rate pegs) in order to achieve price and exchange rate stability. However, for adoption of the other IT type these factors are insignificant, since a single inflation target implies that a central bank focuses primarily on price stability. Third, low government debt increases the probability of adopting IT with a single target, while it is insignificant for the choice of IT with multiple targets. Thus, strong commitment to the single inflation target is complemented by good fiscal discipline, to avoid generat-

[11] The dates of different IT regimes coincide with SIT (for IT with multiple targets) and FFIT (for IT with a single target), as shown in Table 3.1. The exceptions are Australia, Canada, New Zealand, and Spain, for which we specify only IT with a single anchor based on the official IT dates, since they used a single, inflation target from the start.

[12] The methodology is described in Wooldridge (2002, Chapter 15) and Cameron and Trivedi (2005, Chapter 15).

ing inflation for reducing public debt. Additionally, countries with market-based financial systems and higher central bank instrument independence are more likely to adopt IT with multiple targets, while these factors are insignificant for IT with a single inflation target. Finally, two factors have similar impact on the choice of both IT types: countries with floating exchange rates and less developed financial systems are more likely to adopt IT.

This robustness check shows that different factors lead to adopting different IT types. In addition, transition from IT with multiple targets to IT with a single target is affected mainly by lower inflation and output growth, better fiscal discipline, and flexible exchange rate regimes.

Finally, we split the sample into OECD and non-OECD countries. These two groups of countries have different macroeconomic and institutional characteristics, and, therefore, may pursue different objectives of monetary policy. The (lack of) credibility of central banks plays an important role for IT adoption, especially for non-OECD countries. Central banks in OECD countries enjoy high credibility and do not face substantial difficulties in achieving price stability. They adopt IT to maintain low and stable inflation and to acquire a reliable nominal anchor for monetary policy (Bernanke et al., 1999; Freedman and Laxton, 2009). Meanwhile, non-OECD (emerging and developing) countries often suffer from limited credibility of monetary authorities (Amato and Gerlach, 2002). As a result, they do not only search for a good monetary anchor, but also for a way to increase the credibility of their central banks. Strong commitment to an inflation target is unfeasible for these countries during periods of high inflation, since failure to reach a target could undermine the credibility of monetary authorities. These arguments provide motivation for splitting the sample into OECD and non-OECD countries to examine the factors leading to IT adoption. In view of the small number of observations, the results should be interpreted with care.

While the results for the OECD sample are similar to the findings for the full sample, for the non-OECD sample the results are different (columns (2) and (3) of Table 3.4). OECD and non-OECD countries with low inflation, flexible exchange rates, high output volatility, and low government debt are

Table 3.4. **Sensitivity analysis**

| | (1) Full sample, modified for EMU countries | | (2) OECD sample | | (3) Non-OECD sample | | (4) Interaction effects with OECD dummy OECD=1 | | (5) OECD=0 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Inflation | −0.522 | *** | −1.436 | *** | −0.281 | | −0.437 | *** | −0.531 | *** |
| | (0.195) | | (0.446) | | (0.199) | | (0.153) | | (0.192) | |
| Output growth | −0.004 | | −0.005 | | −0.001 | | −0.001 | | −0.004 | |
| | (0.003) | | (0.005) | | (0.003) | | (0.005) | | (0.003) | |
| Output volatility | 0.003 | * | 0.005 | ** | 0.0002 | | 0.002 | | −0.001 | |
| | (0.002) | | (0.002) | | (0.003) | | (0.002) | | (0.002) | |
| Flexible exchange rate regime | 0.070 | *** | 0.061 | ** | 0.082 | ** | 0.058 | ** | 0.073 | ** |
| | (0.022) | | (0.024) | | (0.034) | | (0.027) | | (0.031) | |
| Exchange rate volatility | 0.012 | ** | 0.037 | *** | 0.001 | | 0.029 | *** | 0.005 | |
| | (0.006) | | (0.011) | | (0.006) | | (0.011) | | (0.004) | |
| Fiscal balance | 0.002 | | 0.002 | | −0.003 | | 0.004 | | −0.002 | |
| | (0.004) | | (0.005) | | (0.005) | | (0.004) | | (0.004) | |
| Government debt | −0.001 | ** | −0.002 | *** | 0.0001 | | −0.001 | ** | −0.001 | ** |
| | (0.001) | | (0.001) | | (0.001) | | (0.0004) | | (0.0004) | |
| Trade openness | 0.000 | | 0.001 | ** | −0.0001 | | 0.001 | ** | −0.0001 | |
| | (0.0002) | | (0.0005) | | (0.0003) | | (0.0004) | | (0.0001) | |
| External debt | 0.0001 | | −0.0004 | | −0.0003 | | 0.000 | | −0.0004 | |
| | (0.0003) | | (0.0003) | | (0.001) | | (0.0002) | | (0.003) | |
| Financial instability | −0.004 | | −0.030 | | −0.001 | | 0.011 | | −0.016 | |
| | (0.022) | | (0.031) | | (0.024) | | (0.025) | | (0.028) | |
| Market-based financial structure | 0.023 | | 0.059 | * | 0.003 | | 0.039 | | 0.001 | |
| | (0.023) | | (0.030) | | (0.022) | | (0.026) | | (0.023) | |
| Financial development | −0.057 | ** | −0.088 | *** | 0.026 | | −0.055 | ** | −0.061 | ** |
| | (0.023) | | (0.034) | | (0.033) | | (0.023) | | (0.024) | |
| Central bank instrument independence | 0.011 | | −0.010 | | 0.065 | * | 0.010 | | 0.001 | |
| | (0.022) | | (0.024) | | (0.034) | | (0.024) | | (0.023) | |
| Number of observations | 486 | | 303 | | 259 | | | | | |
| Log-likelihood | −86.66 | | −41.49 | | −32.35 | | | | | |
| Pseudo $R^2$ | 0.15 | | 0.34 | | 0.24 | | | | | |
| Wald $\chi^2$ | 27.74 | *** | 52.78 | *** | 25.05 | ** | | | | |

*Notes:* The table reports average marginal effects and their robust standard errors (in parentheses). ***, **, and * indicate the significance at the 1%, 5%, and 10% significance level, respectively. Wald $\chi^2$ test, equivalent to the F test in linear regression, evaluates the goodness-of-fit of the model.

Table 3.5. **Sensitivity analysis: multinomial probit**

| | Base outcome — non-IT strategy ($y_{it} = 0$) | |
|---|---|---|
| | IT with multiple targets ($y_{it} = 1$) | IT with a single inflation target ($y_{it} = 2$) |
| Inflation | −0.037 | −0.319 *** |
| | (0.040) | (0.079) |
| Output growth | 0.003 | −0.004 ** |
| | (0.002) | (0.002) |
| Output volatility | −0.001 | 0.001 |
| | (0.001) | (0.001) |
| Flexible exchange rate regime | 0.056 *** | 0.067 *** |
| | (0.021) | (0.024) |
| Exchange rate volatility | 0.010 *** | 0.003 |
| | (0.004) | (0.003) |
| Fiscal balance | −0.0001 | 0.002 |
| | (0.002) | (0.002) |
| Government debt | 0.000 | −0.001 *** |
| | (0.0002) | (0.0002) |
| Trade openness | 0.000 | 0.000 |
| | (0.0001) | (0.0001) |
| External debt | −0.0004 *** | 0.000 |
| | (0.0001) | (0.0001) |
| Financial instability | 0.006 | 0.007 |
| | (0.013) | (0.015) |
| Market-based financial structure | 0.041 ** | 0.015 |
| | (0.016) | (0.014) |
| Financial development | −0.060 *** | −0.042 *** |
| | (0.014) | (0.014) |
| Central bank instrument independence | 0.038 *** | 0.003 |
| | (0.013) | (0.014) |
| Number of observations | 573 | |
| Log-likelihood | −197.37 | |
| Wald $\chi^2$ | 104.15 *** | |

*Notes:* This table reports marginal effects and their standard errors (in parentheses). ***, **, and * indicate the significance at the 1%, 5%, and 10% significance level, respectively. Wald $\chi^2$ test, equivalent to the F test in linear regression, evaluates the goodness-of-fit of the model.

more likely to adopt IT. However, whereas openness significantly increases the likelihood to adopt IT in OECD countries, it has an insignificant effect in non-OECD countries. Likewise, central bank instrument independence increases the likelihood to adopt IT in the non-OECD sample, while it is insignificant with a negative sign in the OECD sample.[13] In addition, OECD countries with less developed financial systems are more likely to adopt IT, whereas financial development is insignificant in the non-OECD sample. The occurrence of financial crises is insignificant in both subsamples. The financial structure index is significant only for the OECD sample.

Alternatively, we conduct a robustness check for the full sample and include interaction terms of each variable with the OECD dummy (1 for OECD countries, 0 for non-OECD). This way we can control directly for the differences in factors of IT adoption between the two country groups. Including all interaction terms in a single model leads to a substantial loss of degrees of freedom, which reduces the efficiency of estimates. Therefore, we add interaction terms one by one. We use the method described by Brambor et al. (2006) to calculate interaction effects in nonlinear models. Columns (4)-(5) in Table 3.4 show the results. In these columns we report the interaction effects of each explanatory variable for different values of the OECD dummy.

Our findings suggest that low inflation, a floating exchange rate regime, low government debt, and low financial development are significant factors leading to IT adoption in both country groups. Moreover, the marginal effects of these variables are larger (in absolute value) for non-OECD coun-

[13] One needs to treat this result with caution. Especially for the non-OECD sample, where this variable is positive and significant, the result may be overestimated due to the small number of observations. In addition, a legal index of central bank independence may be a poor proxy for actual independence in emerging and developing countries. The legal index is based on official documents that set legal rules for central banks. However, those rules of law are not always respected. Therefore, we construct an alternative index as: legal index $\times$ rule of law index. The latter is based on the Law and Order index of the International Country Risk Guide database. This proxy for independence is insignificant with a positive sign for non-OECD countries and with a negative sign for OECD countries. It indicates that OECD countries had a low level of actual central bank independence before they adopted IT. Mean value statistics show that the actual index of central bank instrument independence was lower for inflation targeters (both OECD and non-OECD) before the adoption and increased substantially in the post-adoption period.

tries, implying that these factors are more relevant for the decision of non-OECD countries to adopt IT. There are also differences between two country groups in the sign and significance of trade openness and exchange rate volatility. Different signs of the marginal effects are reported for output volatility, fiscal balance, and financial instability.

In conclusion, the sensitivity analyses show that our main results are quite robust to several modifications. The most important new insight is that the factors leading to IT adoption differ between OECD and non-OECD countries. Non-OECD countries that choose to adopt IT have different pre-adoption characteristics than OECD countries. Additionally, different factors lead to the choice of IT with multiple targets and IT with a single target.

## 3.7 Conclusion

This chapter examines factors leading to the countries' decision to adopt IT. While the theoretical literature identifies several important factors affecting the choice for this monetary policy strategy, previous empirical evidence on their actual relevance is incomplete and mixed. We use a large sample of countries to investigate the relevance of macroeconomic, external, fiscal, financial, and institutional factors for the choice of IT. We employ a panel probit model and solve potential endogeneity problem by excluding observations after IT adoption.

Our findings suggest that countries with low inflation, high output and exchange rate volatility, a flexible exchange rate regime, fiscal discipline, less developed financial markets and a market-based financial system are more likely to adopt IT. Moreover, our results point to differences in factors leading to IT adoption between non-OECD and OECD countries. Low inflation, low government debt, a floating exchange rate regime, low financial development, and a high degree of central bank instrument independence are associated with the choice of IT by non-OECD countries.

*Chapter 4*

# Factors of inflation targeting choice — the impact of adoption*

## 4.1 Introduction

This chapter builds upon the study conducted in Chapter 3 and explores the methodological approach used in the analysis of inflation targeting (IT) adoption.

Previous studies that analyze empirically the factors leading to IT choice (e.g., Mishkin and Schmidt-Hebbel, 2001; Hu, 2006; Mukherjee and Singer, 2008), do not differentiate between the factors of IT adoption and the factors of IT continuation. These studies commonly use the full sample for estimation, i.e., they keep observations before and after adoption, until the end of the analyzed period. Such data treatment may cause endogeneity and asymmetry problems, leading to biased results.

In this chapter we examine how the analysis of IT adoption is affected by the choice of methodological approach, i.e., by either keeping or excluding observations for the post-adoption period. We apply panel probit models on the dataset of Chapter 3 and test whether IT adoption leads to a structural

* This chapter is based upon Samarina and Sturm (2013).

change, as a result of which country characteristics influence the choice of IT differently before and after its adoption.

When analyzing the decision to apply or not to apply IT at a specific moment in time, one should take into account which monetary policy strategy a country has so far used (IT or non-IT). To put it differently, the decision to switch from non-IT to IT might not be symmetric to the decision to switch from IT to non-IT. It seems to be institutionally and politically easier to switch from non-IT to IT than vice versa. Hence, we cannot model this process symmetrically. Indeed, the asymmetry is present in real life as we do not observe (at least up to now) any transition from IT to an alternative monetary policy strategy. So far, none of the IT countries has been forced to abandon it. Thus, once a country adopts IT, the self-reinforcing mechanisms make IT enduring (see section 4.2 for further discussion).

Our findings suggest that the decision to adopt IT is different from the decision to maintain IT. The factors related to IT differ significantly between the pre- and post-adoption periods, indicating that IT adoption creates a structural change in institutional and economic characteristics of a country. Most notably, the effect of inflation is largely overestimated in the model including the post-adoption period. Thus, using the full sample (i.e., including the post-adoption period) for analyzing IT adoption leads to biased parameter estimates. This bias causes an overstatement of the importance of variables that are pushed by the actual implementation of IT.

## 4.2 Theoretical framework

IT has proven to be a durable monetary policy strategy: so far no country has been forced to give it up.[1] The possible reason for the high durability of IT is

[1] Note that three EU members (Finland, Spain, and Slovakia) abandoned IT when they joined the euro area. However, this decision was not caused by unsatisfactory economic results, but rather by the institutional commitment of countries to adopt the euro. Thus, their choice to abandon IT was politically predetermined and can be considered as an exception. Additionally, although these countries gave up explicit IT, their new monetary strategy under ECB framework resembles implicit IT and might in the future be transformed into a formal IT strategy (Rose, 2007).

its endogeneity.[2] As an explanation of this endogeneity, we refer to the literature on Optimum Currency Areas (Frankel and Rose, 1996; Rose, 2000). In such studies it is argued that countries are more likely to satisfy the criteria for entry into a currency union *ex post* than *ex ante*. That is, even if a currency union is not an optimal choice for a country at the point of its accession, the process of economic and trade integration will transform the economic fundamentals and institutions in such a way that a currency union becomes an optimal regime after all. Consequently, given the self-reinforcing mechanisms and on top of that the asymmetry in political consequences, it becomes more difficult and costly to exit a currency union than to stay in.

Similar mechanisms may be at work for IT. Although some countries do not satisfy initial conditions for IT adoption, they may choose to apply IT anyway in a belief of its effectiveness in controlling inflation. Once IT is in place, country characteristics and institutions subsequently develop in a way that supports the IT framework. As institutions adjust to functioning under IT, it reinforces the decision of the central bank to maintain IT, making it an endogenously determined optimal choice. In this situation, abandoning IT becomes more difficult than keeping this strategy. The decision to give up IT after years of its implementation may undermine the credibility of the central bank and destabilize inflation expectations.

Given the endogeneity of IT, there is an asymmetry in the monetary strategy choice. That is, the (importance of) factors influencing the decision to continue or exit IT are likely to be different from those affecting the decision to adopt or not adopt IT. This asymmetry is caused by a structural change during and after IT adoption. Ignoring the asymmetry and structural change leads to biased estimation results and inadequate statistical inference.

Therefore, we test the hypothesis:

*IT adoption creates a structural change in economic and institutional conditions. As a result, the factors driving IT adoption are different from those leading to IT*

[2] In this paper, endogeneity of IT is understood in a broader economic sense — endogenous means 'having an internal cause or origin'. Thus, when we say that IT is endogenous, we infer that its continuation is internally affected by the institutions and economic conditions that are shaped under the IT regime.

*continuation.*

Special attention in this analysis is given to inflation, which is considered to be the most important factor driving IT adoption. Previous studies find that lower inflation increases the probability to adopt IT (see Chapter 3). At the same time, the implementation of IT helps to maintain low inflation. As inflation after IT adoption is influenced by the use of IT, the importance of this variable could be overstated. Thus, we expect that the effect of inflation on the probability of IT adoption is overestimated in models that do not distinguish between the pre- and post-adoption periods.

## 4.3 Methodology

The study employs a panel binary choice model where the dependent variable $y_{it}$ ($i = 1, \ldots, N; t = 1, \ldots, T$) takes the value 1 if country $i$ implements IT in year $t$, and 0 otherwise. We use a probit specification and estimate two types of models: (i) random effects probit to account for unobserved cross-country heterogeneity; (ii) pooled probit with standard errors clustered at the country level to control for serial correlation across time.[3]

To test whether the explanatory variables influence the probability of IT choice differently before and after IT adoption, we employ a structural break analysis. Let $D(\tau)$ be a time function, where $\tau$ measures the duration of IT in years, starting from 0 in the adoption year. The unrestricted model has the form:

$$\begin{aligned} &\Pr(y_{it} = 1 | \boldsymbol{X}_{i,t-1}, D(\tau), \mu_i) = \\ &\qquad \Phi(\alpha + \boldsymbol{\beta}' \boldsymbol{X}_{i,t-1} + \theta' D(\tau) + \boldsymbol{\lambda}' (\boldsymbol{X}_{i,t-1} \times D(\tau)) + \mu_i), \end{aligned} \tag{4.1}$$

where $y_{it} = 1$ if $y_{it}^* > 0$, $y_{it} = 0$ if $y_{it}^* \leq 0$, $y_{it}^*$ is an unobserved latent variable which describes the decision to adopt IT; $\Phi(.)$ is a cumulative distribution function of a standard normal distribution; $\alpha$ is a constant term;

[3] We do not estimate a fixed effects model because it drops the entire control group, i.e., all countries that did not adopt IT. For this reason, a fixed effects model has not been used in previous studies of IT adoption either.

$\boldsymbol{\beta}, \theta, \boldsymbol{\lambda}$ are vectors of parameters to be estimated; $\boldsymbol{X}_{i,t-1}$ is a matrix of explanatory variables, lagged one year, as current decisions of central banks rely on the history of analyzed factors; $\boldsymbol{X}_{i,t-1} \times D(\tau)$ is a matrix of interaction terms between the explanatory variables and $D(\tau)$; $\mu_i$ are random effects, uncorrelated with the regressors, $\mu_i | \boldsymbol{X}_{i,t-1}, D(\tau) \sim \mathcal{N}(0, \sigma_\mu^2)$.

Given that the adjustment of country characteristics to IT implementation is a gradual process, we introduce $D(\tau)$ as a smooth transition function. Such specification takes into account the fact that it may take more than one year to accommodate the economic conditions and institutions so as to be compatible with the IT framework. For $\tau > 0$, $D(\tau)$ is specified as:
1) $D(\tau) = e^{-\rho/\tau}$; $\rho \geq 0$, $\rho$ is a decay parameter; a larger value of $\rho$ means a slower transition;
2) $D(\tau) = 1 - e^{(-\gamma\tau^2)}$; $\gamma > 0$, $\gamma$ is the speed of transition; a smaller value of $\gamma$ implies a slower transition.

In the estimations, we will use both specifications of $D(\tau)$ to examine the sensitivity of results to the choice of the smooth transition function.

For the pre-adoption period, $\tau = 0$ and $D(\tau) = 0$, the estimated parameters for the explanatory variables correspond to vector $\boldsymbol{\beta}$. For the post-adoption period, $\tau > 0$ and $D(\tau) > 0$, the estimated parameters are $\boldsymbol{\beta}$, $\theta$, and $\boldsymbol{\lambda}$.

The restricted model has the form:

$$\Pr(y_{it} = 1 | \boldsymbol{X}_{i,t-1}, \mu_i) = \Phi(\alpha + \boldsymbol{\beta}' \boldsymbol{X}_{i,t-1} + \mu_i). \tag{4.2}$$

The estimation procedure is the following: first we estimate the restricted model; then, we fit the unrestricted model with different specifications of $D(\tau)$ and use a Wald test to test for the joint significance of the interaction terms and $D(\tau)$. Testing for a structural break implies the following null and alternative hypotheses:
$H_0$: there is no structural break, i.e. all interaction terms with $D(\tau)$ plus $D(\tau)$ itself have jointly insignificant coefficient estimates;
$H_1$: there is a structural break after IT adoption, i.e. either the coefficient of

$D(\tau)$ or at least one of interaction terms are significantly different from zero.

Additionally, to show how the findings could be affected by excluding the post-adoption period, we estimate the model in (4.2) while removing observations on countries after they adopt IT, as was done in Chapter 3.

## 4.4 Data

We use the dataset from Chapter 3, consisting of 60 countries (30 IT and 30 non-IT) over the period 1985–2008. We conduct estimations for official adoption dates according to the central banks' documents (see Table 3.1).[4]

We analyze 12 explanatory variables associated with IT choice, namely: inflation, output growth, output volatility, exchange rate regime, exchange rate volatility, fiscal balance, government debt, trade openness, external debt, market-based financial structure, financial development, and an index for actual central bank instrument independence (ACBI independence).[5] These variables are analyzed in previous studies as potential factors leading to IT adoption (e.g., Hu, 2006; Mukherjee and Singer, 2008). First, we include 6 explanatory variables that are found significant in Chapter 3. These are: inflation, output volatility, flexible exchange rate regime dummy, exchange rate volatility, government debt, and financial development. Subsequently, we extend the model and examine all 12 variables.

## 4.5 Empirical results

Tables 4.1 and 4.2 present the estimation results for random effects probit and pooled probit models, respectively. First, we fit the model with 6 and then with 12 explanatory variables. We report average partial effects at $\bar{\mu} = 0$ for random effects probit and average marginal effects for pooled probit. In the transition function $D(\tau)$ we set $\rho$ and $\gamma$ equal to 1, which implies

[4] The estimation results using alternative adoption dates for soft IT and full-fledged IT are qualitatively similar and available on request.

[5] See Chapter 3 and Table B.1 (Annex) for a description and the data sources of the explanatory variables.

a transition half-life (i.e. when $D(\tau) = 0.5$) of 17 months and 10 months, respectively.

We also report the estimation results for the models as specified in Equation (4.2), where we exclude the post-adoption period for IT countries.

The Wald test statistics indicate that all interaction terms with $D(\tau)$ plus $D(\tau)$ itself are jointly significant in the unrestricted models. Thus, we reject the null hypothesis in favor of the alternative that there is a structural break after IT adoption.

Our results point to substantial differences between restricted and unrestricted models in terms of significance and magnitude of marginal/partial effects for the explanatory variables. In the unrestricted models we find significant but smaller effects (in an absolute sense) for inflation, exchange rate regime, exchange rate volatility, and financial development.[6] Especially noteworthy is the finding that in the unrestricted models the estimated effects of inflation are substantially different from the restricted models, pointing to a large overestimation bias in the latter. This result is in line with our argument that the impact of inflation on the decision to apply IT changes considerably after IT adoption. Furthermore, in the random effects probit models the estimates of government debt turn significant in the unrestricted models, whereas output volatility, trade openness, external debt, and market-based financial structure become insignificant. The remaining variables do not show noticeable changes. The results for the pooled probit models are comparable to the ones for the random effects probit models.

Comparing the results for the restricted model and the model excluding the post-adoption period, we find considerable differences between the two. All marginal/partial effects are much smaller (in absolute values) in the model without the post-adoption period. Thus, including the post-adoption period leads to overestimation bias in the analysis of factors leading to IT adoption. This bias could be eliminated by excluding observations on countries after they adopt IT.

[6] The only exceptions are financial development and exchange rate variables in the unrestricted random effects probit specification with 12 explanatory variables. As compared to the restricted model, the estimated effects turn out somewhat larger in an absolute sense.

Table 4.1. **Estimation results — random effects probit**

| Variables | Restricted | Unrestricted $D(\tau)=e^{-1/\tau}$ | Unrestricted $D(\tau)=1-e^{-\tau^2}$ | Without post-adoption period | Restricted | Unrestricted $D(\tau)=e^{-1/\tau}$ | Unrestricted $D(\tau)=1-e^{-\tau^2}$ | Without post-adoption period |
|---|---|---|---|---|---|---|---|---|
| Inflation | −3.483 *** | −0.566 *** | −0.496 *** | −0.362 ** | −1.788 *** | −0.926 ** | −0.876 ** | −0.704 * |
| | (1.050) | (0.209) | (0.190) | (0.186) | (0.314) | (0.374) | (0.362) | (0.401) |
| Output volatility | −0.006 * | 0.0005 | 0.0005 | 0.0005 | −0.003 * | 0.002 | 0.002 | 0.002 |
| | (0.003) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.002) | (0.002) |
| Flexible exchange rate regime | 0.094 *** | 0.061 *** | 0.060 *** | 0.053 *** | 0.034 *** | 0.071 *** | 0.071 *** | 0.073 *** |
| | (0.035) | (0.019) | (0.019) | (0.019) | (0.014) | (0.025) | (0.025) | (0.027) |
| Exchange rate volatility | 0.015 * | 0.013 ** | 0.012 *** | 0.011 *** | 0.008 * | 0.012 * | 0.012 * | 0.013 * |
| | (0.009) | (0.005) | (0.005) | (0.004) | (0.005) | (0.007) | (0.006) | (0.007) |
| Government debt | 0.001 | −0.001 * | −0.001 * | −0.001 ** | −0.0003 | −0.001 * | −0.001 * | −0.001 ** |
| | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Financial development | 0.118 ** | −0.033 | −0.032 | −0.032 * | −0.058 ** | −0.069 ** | −0.066 ** | −0.062 ** |
| | (0.050) | (0.022) | (0.021) | (0.018) | (0.024) | (0.035) | (0.034) | (0.032) |
| Output growth | | | | | 0.0001 | −0.005 | −0.004 | −0.004 |
| | | | | | (0.002) | (0.003) | (0.003) | (0.003) |
| Fiscal balance | | | | | −0.002 | −0.0001 | −0.0001 | 0.001 |
| | | | | | (0.002) | (0.003) | (0.003) | (0.003) |
| Trade openness | | | | | 0.002 *** | 0.0001 | 0.0001 | 0.000 |
| | | | | | (0.000) | (0.000) | (0.000) | (0.000) |
| External debt | | | | | 0.0002** | 0.000 | 0.000 | −0.0001 |
| | | | | | (0.000) | (0.000) | (0.000) | (0.000) |
| Market-based financial structure | | | | | −0.089 *** | 0.004 | 0.003 | 0.019 |
| | | | | | (0.022) | (0.026) | (0.026) | (0.024) |
| ACBI independence | | | | | −0.0004 | −0.001 | −0.001 | −0.0001 |
| | | | | | (0.003) | (0.004) | (0.004) | (0.005) |
| Observations | 1009 | 1009 | 1009 | 753 | 809 | 809 | 809 | 562 |
| Log-likelihood | −240.01 | −134.99 | −128.60 | −104.97 | −179.65 | −100.70 | −98.90 | −88.01 |
| Wald test $p$-value | | 0.00 | 0.00 | | | 0.00 | 0.00 | |

*Notes:* The table reports average partial effects and their standard errors (in parentheses). Interaction terms are included in unrestricted models, but not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Wald test $p$-value indicates the significance level for rejecting the null hypothesis of joint insignificance of interaction terms and $D(\tau)$.

Table 4.2. **Estimation results — pooled probit**

| Variables | Restricted | Unrestricted | | Without post-adoption period | Restricted | Unrestricted | | Without post-adoption period |
|---|---|---|---|---|---|---|---|---|
| | | $D(\tau)=e^{-1/\tau}$ | $D(\tau)=1-e^{-\tau^2}$ | | | $D(\tau)=e^{-1/\tau}$ | $D(\tau)=1-e^{-\tau^2}$ | |
| Inflation | −2.651 *** | −0.359 *** | −0.323 ** | −0.325 ** | −3.326 *** | −0.417 *** | −0.407 ** | −0.490 ** |
| | (0.652) | (0.146) | (0.131) | (0.132) | (0.926) | (0.180) | (0.175) | (0.212) |
| Output volatility | −0.002 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| | (0.006) | (0.001) | (0.001) | (0.001) | (0.007) | (0.001) | (0.001) | (0.002) |
| Flexible exchange rate regime | 0.236 *** | 0.055 *** | 0.053 *** | 0.050 *** | 0.258 *** | 0.059 *** | 0.059 *** | 0.065 *** |
| | (0.058) | (0.016) | (0.016) | (0.017) | (0.061) | (0.016) | (0.016) | (0.021) |
| Exchange rate volatility | 0.055 *** | 0.011 *** | 0.011 *** | 0.011 *** | 0.060 *** | 0.009 ** | 0.009 ** | 0.011 ** |
| | (0.017) | (0.004) | (0.004) | (0.004) | (0.020) | (0.004) | (0.004) | (0.005) |
| Government debt | −0.002 | −0.001 ** | −0.001 ** | −0.001 ** | −0.002 | −0.001 ** | −0.001 ** | −0.001 ** |
| | (0.002) | (0.0003) | (0.0003) | (0.0003) | (0.002) | (0.0004) | (0.0004) | (0.0005) |
| Financial development | −0.082 | −0.032 * | −0.030 * | −0.031 * | −0.154 * | −0.046 ** | −0.045 ** | −0.054 ** |
| | (0.080) | (0.019) | (0.018) | (0.018) | (0.092) | (0.019) | (0.018) | (0.023) |
| Output growth | | | | | −0.002 | −0.003 | −0.003 | −0.004 |
| | | | | | (0.008) | (0.002) | (0.002) | (0.002) |
| Fiscal balance | | | | | 0.014 | 0.002 | 0.002 | 0.002 |
| | | | | | (0.010) | (0.003) | (0.003) | (0.004) |
| Trade openness | | | | | −0.0003 | 0.000 | 0.000 | 0.000 |
| | | | | | (0.001) | (0.0002) | (0.0002) | (0.0002) |
| External debt | | | | | 0.0003 | 0.000 | 0.000 | 0.000 |
| | | | | | (0.005) | (0.0001) | (0.0001) | (0.0001) |
| Market-based financial structure | | | | | 0.047 | 0.016 | 0.015 | 0.019 |
| | | | | | (0.084) | (0.016) | (0.016) | (0.019) |
| ACBI independence | | | | | 0.000 | −0.0003 | −0.001 | −0.001 |
| | | | | | (0.017) | (0.003) | (0.003) | (0.004) |
| Observations | 1009 | 1009 | 1009 | 753 | 809 | 809 | 809 | 562 |
| Log-likelihood | −468.82 | −139.78 | −132.20 | −105.01 | −396.11 | −104.39 | −101.90 | −88.17 |
| Wald test $p$-value | | 0.00 | 0.00 | | | 0.00 | 0.00 | |

*Notes:* The table reports average marginal effects and their robust standard errors (in parentheses). Interaction terms are included in unrestricted models, but not reported. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Wald test $p$-value indicates the significance level for rejecting the null hypothesis of joint insignificance of interaction terms and $D(\tau)$.

Since $\rho$ and $\gamma$ cannot be easily estimated, we conduct a robustness analysis to check how sensitive the results are to the choice of $\rho$ and $\gamma$.[7] Figures 4.1 and 4.2 show the estimated effects across different values of $\rho$ and $\gamma$, respectively, that are used to measure half-lives of transition. In Figure 4.1 the half-life of transition varies from 3.5 months (i.e. $\rho = 0.2$) to 69 months (i.e. $\rho = 4$), while in Figure 4.2 the half-life of transition varies from 45 months (i.e. $\gamma = 0.05$) to 6 months (i.e. $\gamma = 3$). We show the graphs for models including 6 explanatory variables (the results using 12 variables are comparable and available on request).[8] We find that the outcomes with the exception of inflation do not vary substantially across $\rho$ and $\gamma$ in terms of sign and significance of the estimated effects. For inflation, the estimated effects become much smaller (in absolute value) as transition is allowed to go faster. Moreover and as to be expected, the slower is the transition to IT (corresponding to a higher half-life of transition), the closer our estimates get to the restricted model. However, even for a very slow transition, the results from the unrestricted models remain significantly different from the restricted model.

The comparison between the restricted and unrestricted models shows that using the assumption that the factors explaining IT adoption do not depend upon the monetary regime in place is rejected by the data. Studies that rely on this assumption tend to overestimate the effects of crucial economic factors, such as inflation, exchange rate regime, financial development, fiscal discipline, and trade openness on the probability of countries to start applying IT (e.g., Hu, 2006; Mukherjee and Singer, 2008).

[7] Alternatively, one could apply non-linear techniques to program the estimation of $\rho$ and $\gamma$. This remains a task for future work.

[8] The variables shown on the graphs include: inflation (INFL), output volatility (OUTVOL), a flexible exchange rate regime dummy (EXRATE), exchange rate volatility (EXRVOL), government debt (GOVDEBT), and financial development (FINDEV).

Figure 4.1. **Average partial/marginal effects for $D(\tau) = e^{-\rho/\tau}$**

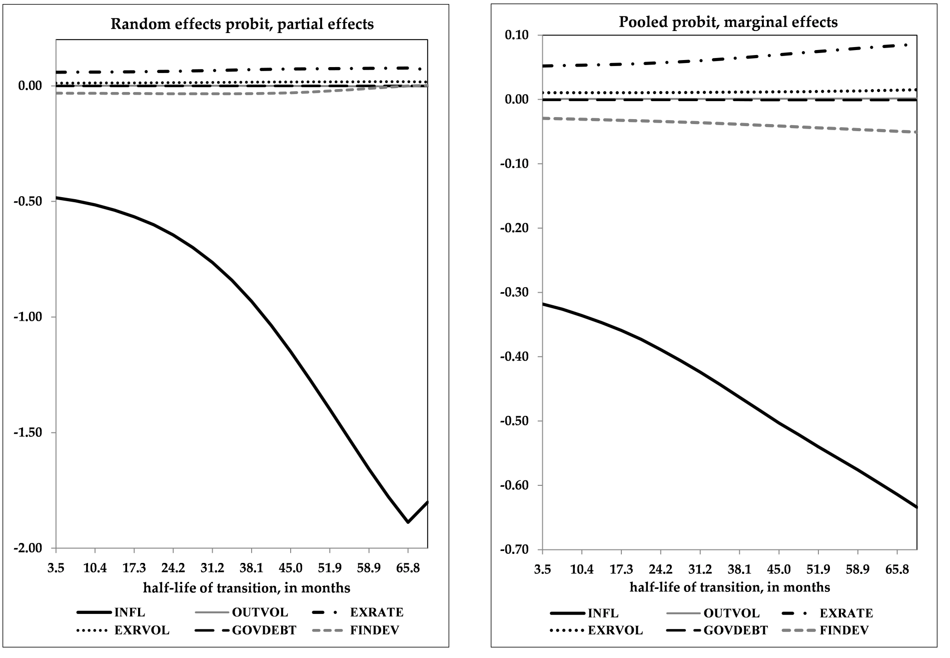
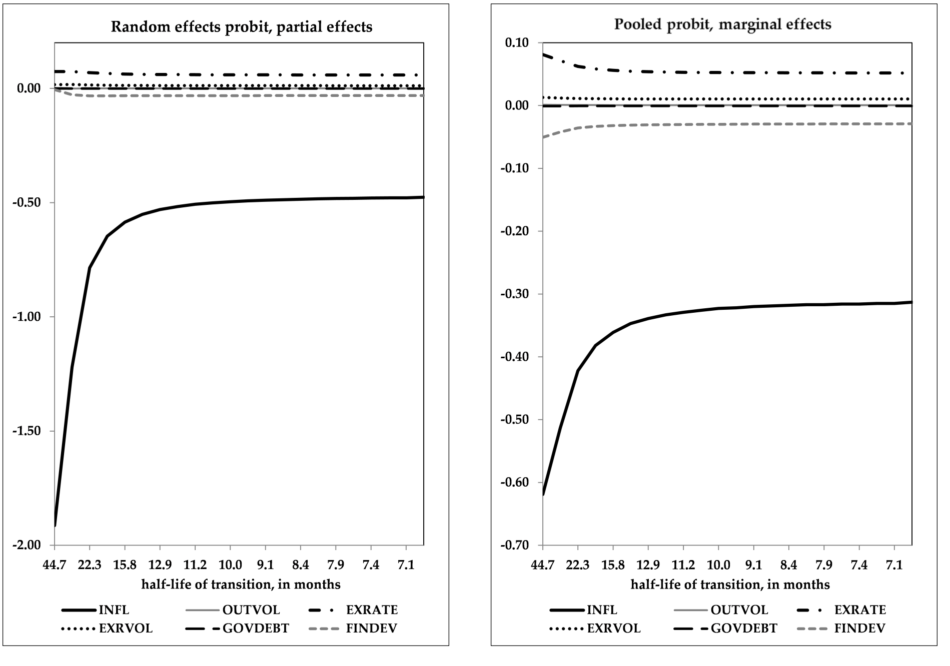



Figure 4.2. **Average partial/marginal effects for $D(\tau) = 1 - e^{(-\gamma\tau^2)}$**



## 4.6 Conclusion

This chapter examines how the selection of the time period affects the analysis of IT adoption and tests whether country characteristics influence the probability to use IT differently before and after adoption. We find that there is a structural change in economic and institutional characteristics occurring during and after IT adoption. The factors leading to IT adoption differ significantly between the periods before and after adoption due to the asymmetry and endogeneity of IT. Importantly, the effect of inflation on the probability of IT adoption is largely overestimated in the model including the post-adoption period. Hence, using the full sample for analyzing the determinants of IT adoption produces biased parameter estimates. Excluding all the observations after the IT adoption date eliminates this bias. This approach has been applied in Chapter 3 of this thesis.

*Chapter 5*

# Spatial interactions in inflation targeting adoption: a spatial probit approach*

## 5.1 Introduction

In the previous two chapters we investigated different country characteristics that may lead to inflation targeting (IT) adoption. However, the decision of countries to apply IT could be influenced not only by their own characteristics but also by the monetary strategy choices of other countries.

Previous studies on IT adoption ignore spatial interdependence between countries in their decisions to adopt or not to adopt IT; consequently, they use ordinary binary choice models. To our knowledge, only Mukherjee and Singer (2008) analyze the decision of 78 countries to adopt IT dependent on the decisions taken by other countries using time-series cross-sectional data over the period 1987–2003. These authors find that the probability that a country will adopt IT increases if other (neighboring) countries have preceded. However, by just pooling cross-sectional data over time, they implicitly assume that the period that has expired since a neighboring country has decided to adopt IT, has no impact. In addition, they assume that neigh-

* This chapter is based upon Elhorst et al. (2013).

boring countries that did not adopt yet, have the same impact as countries that already switched to IT.

In this chapter we apply spatial econometrics to explore spatial interactions between countries in IT adoption. We construct a spatial probit model with two spatially lagged variables, one for countries that did not adopt IT yet and one for countries that already transferred to IT. The parameters of this model will be estimated based on observations of those countries that are still using non-IT strategies at the start of the different time periods considered; observations on countries after they switched to IT are removed. The dependent variable and the first spatial term are both specified in terms of unobserved choices, i.e. the willingness to adopt IT, while the second spatial term is specified in terms of observed choices, i.e., the actual adoption. Consequently, we allow countries that did not adopt IT yet to have a different impact than countries that already adopted.

The standard spatial probit model may be used to explain interaction effects among geographical units when the dependent variable takes the form of a binary response variable. However, one shortcoming of this model is that it cannot be used to explain the transition from one state to another when this transition for one geographical unit takes place at a different moment in time than for another unit.

These and related issues have been discussed in the literature on duration modeling (see Cameron and Trivedi, 2005, Chapter 17). Generally, duration models are used to explain the time that has passed to the moment when unit $i$ transfers from one state to another.[1] This literature has produced two results that are relevant for our study. First, if the data are observed in discrete time intervals, one can use a discrete-time transition model, since in each time interval two outcomes are possible: the transition to the different state takes place or it does not (Cameron and Trivedi, 2005, p. 602). A probit model which restricts the coefficients of the regressors to be constant over time, except for the intercept, is then a straightforward and legitimate choice. Second, observations on units after they transferred to another

[1] A well-known example is the Cox proportional hazard model (Cox, 1972).

state are generally removed from the sample. This is because explanatory variables that change over time may exhibit feedback and hence may not be strictly exogenous; once a unit has transferred to another state, the explanatory variables may change as a result of this transition.

The standard probit model as suggested in Cameron and Trivedi (2005) for duration data is not appropriate for our setting since individual units are treated as independent entities. Interaction effects result in additional complications. In duration models the process that is observed may have begun at different points in time for different units in the sample. In our setting not only the time that has passed before units transfer to state 1 is important, but also the time that has passed since the transfer of other units. Therefore, the transfer process can only be modeled adequately if the starting point of the observation period is the same for every unit in the sample.

The rest of this chapter is structured as follows. Section 5.2 reviews the literature on spatial probit models. A detailed description of our model is provided in section 5.3. Section 5.4 describes the data, while section 5.5 presents the empirical results. Section 5.6 concludes.

## 5.2 Spatial probit models: a review

### The spatial error probit model

The basic spatial probit model is a linear regression model with spatially correlated error terms $\varepsilon_i$ for a cross-section of $N$ observations ($i = 1, \ldots, N$). In vector notation, the spatial error probit model reads as

$$\boldsymbol{Y}^* = \boldsymbol{X\beta} + \boldsymbol{\varepsilon}, \qquad \boldsymbol{\varepsilon} = \lambda \boldsymbol{W\varepsilon} + \boldsymbol{v}, \tag{5.1}$$

where $\boldsymbol{Y}^*$ is an $N \times 1$ vector consisting of one observation on the latent dependent variable for every unit in the sample, and $\boldsymbol{X}$ is an $N \times K$ matrix of explanatory variables with parameters contained in a $K \times 1$ vector $\boldsymbol{\beta}$. $\boldsymbol{\varepsilon} = (\varepsilon_1, \ldots, \varepsilon_N)'$ and $\boldsymbol{v} = (v_1, \ldots, v_N)'$ represent the error terms of the model; $\boldsymbol{\varepsilon}$ reflects the spatially correlated error term with the coefficient $\lambda$, while $\boldsymbol{v}$ follows a multivariate normal distribution with mean $\mathbf{0}$ and variance $\boldsymbol{I}$. We use $\boldsymbol{I}$ rather than $\boldsymbol{\sigma^2 I}$ here since $\boldsymbol{\beta}$ and $\boldsymbol{\sigma^2}$ cannot be separately identified. For this reason, $\sigma^2$ is set to 1. $\boldsymbol{W}$ is an $N \times N$ pre-specified non-negative spatial weights matrix describing whether or not the spatial units in the sample are neighbors of each other. Its diagonal elements are zero, since no unit can be viewed as its own neighbor. Usually, the spatial weights matrix is normalized such that the elements of each row sum to one. The spatial error model is consistent with a situation where determinants of the dependent variable omitted from the model are spatially autocorrelated, and with a situation where unobserved shocks follow a spatial pattern. The spatial error probit model in (5.1) can be rewritten as

$$\boldsymbol{Y}^* = \boldsymbol{X\beta} + \boldsymbol{\varepsilon} = \boldsymbol{X\beta} + (\boldsymbol{I} - \lambda \boldsymbol{W})^{-1}\boldsymbol{v}, \tag{5.2}$$

which implies that the covariance matrix of $\boldsymbol{\varepsilon}$ is $\boldsymbol{\Omega}_\lambda = [(\boldsymbol{I} - \lambda\mathbf{W})'(\mathbf{I} - \lambda\mathbf{W})]^{-1}$.

The basic problem that needs to be solved in estimating this model is that the likelihood function cannot be written as the product of $N$ one-dimensional normal probabilities as is the case with a standard (non-spatial) probit model. This is because individual error terms $\varepsilon_i$ ($i = 1, \ldots, N$) are dependent on each other, as a result of which the likelihood function is an $N$-dimensional integral:

$$L(\boldsymbol{\beta}, \lambda) = \int_{\boldsymbol{Y}^*} \frac{1}{(2\pi)^{N/2}|\boldsymbol{\Omega}_\lambda|^{1/2}} exp\left\{-\frac{1}{2}\boldsymbol{\varepsilon}'\boldsymbol{\Omega}_\lambda^{-1}\boldsymbol{\varepsilon}\right\} d\boldsymbol{\varepsilon}. \tag{5.3}$$

Another problem might be the inversion of the matrix $(\boldsymbol{I} - \lambda\boldsymbol{W})$ for large values of $N$ when using a numerical algorithm to find the optimum of $\lambda$, especially if this inversion needs to be repeated several times. This is because the number of steps which most algorithms require to determine the inverse of an $N \times N$ matrix is proportional to $N^3$. Nevertheless, for small or moderate values of $N$ (<1000) this is not really a problem. The spatial error probit model has mainly been used to present solutions to these methodological problems (see McMillen (1992), Pinkse and Slade (1998), LeSage (2000), Beron and Vijverberg (2004), Fleming (2004), and Klier and McMillen

(2008)), but it has rarely been used in empirical applications.

### The spatial lag probit model

Another popular spatial probit model is the spatial lag probit model: a linear regression model with endogenous interaction effects among the unobserved dependent variable:

$$\boldsymbol{Y}^* = \rho \boldsymbol{W}\boldsymbol{Y}^* + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{v}, \tag{5.4}$$

where $\rho$ is the spatial autoregressive coefficient. Endogenous interaction effects are typically considered as the formal specification for the equilibrium outcome of a spatial or social interaction process, in which the value of the dependent variable for one agent is jointly determined with that of neighboring agents. By rewriting the spatial lag probit model as

$$\boldsymbol{Y}^* = (\boldsymbol{I} - \rho \boldsymbol{W})^{-1}\boldsymbol{X}\boldsymbol{\beta} + (\boldsymbol{I} - \rho \boldsymbol{W})^{-1}\boldsymbol{v} = (\boldsymbol{I} - \rho \boldsymbol{W})^{-1}\boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \tag{5.5}$$

it can be seen that the covariance matrix of $\boldsymbol{\varepsilon}$ in this model is similar to that of spatial error probit, $\boldsymbol{\Omega}_\rho = [(\boldsymbol{I} - \rho \boldsymbol{W})'(\boldsymbol{I} - \rho \boldsymbol{W})]^{-1}$, the difference being that the parameter $\lambda$ is replaced by $\rho$. To estimate this model, not only the integration of $N$-dimensional integral needs to be accounted for, but also the endogeneity of the variable $\boldsymbol{W}\boldsymbol{Y}^*$. Many studies have considered this model from a methodological viewpoint: McMillen (1992), LeSage (2000), Beron and Vijverberg (2004), Fleming (2004), Klier and McMillen (2008), LeSage and Pace (2009, Chapter 10), Franzese Jr. and Hays (2010), Pace and LeSage (2012). It has also been used in many empirical studies, among which, Mukherjee and Singer (2008) and LeSage et al. (2011).

An important variant of the spatial lag probit model for the analysis to be conducted in this chapter is

$$\boldsymbol{Y}^* = \rho \boldsymbol{W}\boldsymbol{Y} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{v}, \tag{5.6}$$

where the latent dependent variable $\boldsymbol{Y}^*$ depends on observed choices represented by $\boldsymbol{WY}$ rather than unobserved ones. The only application of this model we could find is Qu and Lee (2012). They derive LM tests for spatial correlation in a standard probit model not only if the alternative model is Equation (5.4) but also if the model is Equation (5.6). Soetevent and Kooreman (2007) apply Equation (5.6) to analyze social interactions in the behavior of teens at high school. They assume that the unobserved choice of individual $i$ depends on the observed choices of other individuals. One of the basic problems of this interaction model is that it does not have a unique equilibrium, but different equilibria depending on the sign of the interaction parameter $\rho$ and on the sample size $N$ (Soetevent and Kooreman, 2007, Propositions 2 and 3). To estimate the model they assume that the probability that one particular equilibrium occurs is equal to one over the total number of equilibria.

**Estimation methods**

The expectation-maximization (EM) algorithm adapted by McMillen (1992) for the spatial probit model is one of the earliest attempts to deal with the multidimensional integration problem. The E-step takes the expectation of the log-likelihood function for the latent variable $y_i^*$ conditional on its observed value $y_i$ and the parameter vector. The initial parameter vector is obtained by estimating the spatial model as if the dependent variable is continuous, while subsequent values are obtained from the previous iteration. The M-step maximizes the likelihood function for the parameter vector conditional on the expected value of $y_i$ obtained from the E-step, which boils down to estimating a regular spatial model for a continuous variable. These steps are then repeated until the parameter vector converges. This algorithm, however, has been severely criticized. First, there is a substantial computational burden in the repetitions of the algorithm (Fleming, 2004). Second, it does not produce an estimate of the variance-covariance matrix needed to determine the standard errors and t-values of the parameter estimates (LeSage, 2000; Fleming, 2004). It should be stressed that this is because of another methodological shortcoming that has not been discussed in the literature before. Whereas the expectation of the latent variable $y_i^*$ in the EM algorithm is determined conditional on the observed value $y_i$ of the unit itself, it should be determined conditional on the observed values of *all* other units. Consequently, this algorithm produces inconsistent parameter estimates.

A similar type of problem applies to the Bayesian MCMC estimation procedure initially developed by LeSage (2000). This procedure is based on sequentially drawing model parameters from their conditional distributions. This process of sampling parameters continues until the distribution of draws converges to the targeted joint posterior distribution of the model parameters. Two different sampling schemes are used: the Gibbs sampler for model parameters that have standard conditional distributions ($\boldsymbol{\beta}$, $\boldsymbol{Y}^*$), and the Metropolis-Hastings sampler for the spatial parameter $\lambda$ in the spatial error model or $\rho$ in the spatial lag model, both of which have a non-standard distribution (LeSage and Pace, 2009, Chapter 7). The key problem is to sample $\boldsymbol{Y}^*$. In LeSage (2000), the individual elements of $\boldsymbol{Y}^*$ are obtained by sampling from a sequence of univariate truncated normal distributions. In later work, LeSage and Pace (2009, p. 285) point out that "this *cannot* be done for the case of a truncated multivariate distribution" (emphasis in original). Draws for individual elements $y_i^*$ should be based on the distribution of $y_i^*$ conditional on all other $N-1$ elements $[y_1^*, \ldots, y_{i-1}^*, y_{i+1}^*, \ldots, y_N^*]$. Probably because James LeSage has made a Matlab routine of the (improved) Bayesian MCMC estimator of the spatial lag probit model available at his website (`www.spatial-econometrics.com`), it has been frequently used in empirical research (Mukherjee and Singer, 2008; Wang and Kockelman, 2009; LeSage et al., 2011). Another reason might be that Bayesian MCMC is faster than other estimation techniques (Franzese Jr. and Hays, 2010). One drawback of the Bayesian MCMC is that it is difficult to verify whether convergence actually occurs. In some experiments we carried out it clearly did not, even though LeSage's Matlab routine simply reported final estimation results after the pre-specified number of draws had been passed through. Choosing starting values sometimes helps but not always. In addition, the convergence to the joint posterior distribution is sometimes sensitive to the choice of the prior distributions (Franzese Jr. and Hays, 2010).

A third estimation method is Generalized Method of Moments (GMM), initially proposed by Pinkse and Slade (1998) for the estimation of a spatial error probit model. To deal with the endogeneity of the spatially lagged dependent variables in case of the spatial lag model, the variable $\boldsymbol{WY}^*$ is instrumented by $[\boldsymbol{X}\ \boldsymbol{WX}\ldots\boldsymbol{W}^g\boldsymbol{X}]$, where $g$ is a pre-selected constant. Typically, one would take $g = 1$ or $g = 2$, dependent on the number of regressors and the type of model (see Kelejian et al., 2004). To avoid repeated inversions of the matrix $(\boldsymbol{I} - \lambda\boldsymbol{W})$, they linearize spatial parameters around the non-spatial parameter values that are obtained from a standard (non-spatial) probit or logit model. GMM studies do not specify the distribution function of the error terms, and therefore do not solve the multidimensional integration problem. Moreover, they ignore spatial interaction effects among the error terms.[2]

This chapter adopts a maximum likelihood estimation method. Starting from McMillen (1992), Beron and Vijverberg (2004) developed a Simulated Maximum Likelihood (SML) estimator for the spatial lag probit model. This simulation method is known as Recursive-Importance-Sampling (RIS) and relies on Monte Carlo simulation of truncated multivariate normal distributions, as discussed by Vijverberg (1997). First, a lower-triangular Cholesky matrix of the variance-covariance matrix of the error terms is determined, and then the multidimensional integral in Equation (5.3) is evaluated. Originally, Vijverberg (1997) considered four different density functions: the logit, normal, t and a transform of the Beta(2,2). Although relatively slow, Beron and Vijverberg (2004) favor the normal distribution for its efficiency. These authors also point out that the RIS-normal simulator is identical to the Geweke-Hajivassiliou-Keane (GHK) simulator (Börsch-Supan and Hajivassiliou, 1993; Keane, 1993). The advantage of this estimation method is that it provides a feasible and efficient algorithm to approximate the $N$-dimensional truncated normal density function needed to maximize the

[2] See Elhorst et al. (2013) for details.

log-likelihood function. A more detailed explanation is given in the next section. Franzese Jr. and Hays (2010) compare the performance of different estimation methods of the spatial lag probit model and find that the RIS simulator produces more efficient estimates of the spatial parameter $\rho$ than Bayesian MCMC. However, the RIS procedure turns out to be computationally intensive and time-consuming. Recently, Pace and LeSage (2012) called the GHK/RIS simulator one of the most effective techniques for computing the $N$-dimensional truncated normal distribution. They also suggest several sparse matrix algorithms to speed up computation time. Unfortunately, their Matlab routines are not available yet.

## 5.3 Methodology

### 5.3.1 Model

Suppose there are two states, 0 and 1, that $y_{it}$ denotes the state a particular unit $i$ ($i = 1, \ldots, N$) is in at time $t$ ($t = 1, \ldots, T$). We are interested in the determinants of transition from state 0 to state 1. The transition from one state to another for one unit takes place at a different moment in time than for another unit. To deal with this issue we assume that the data are sorted; first the units that are in state 0 at the start of time period $t$ ($\mathbf{Y}_t^{0*}$) followed by the units that are already in state 1 at the start of period $t$ ($\boldsymbol{Y}_t^{1*}$). We initially propose the following spatial probit model:

$$\begin{pmatrix} \boldsymbol{Y}_t^{0*} \\ \boldsymbol{Y}_t^{1*} \end{pmatrix} = \rho \begin{pmatrix} \boldsymbol{W}_t^{00} & \boldsymbol{W}_t^{01} \\ \boldsymbol{W}_t^{10} & \boldsymbol{W}_t^{11} \end{pmatrix} \begin{pmatrix} \boldsymbol{Y}_t^{0*} \\ \boldsymbol{Y}_t^{1*} \end{pmatrix} + \begin{pmatrix} \boldsymbol{X}_t^{0} \\ \boldsymbol{X}_t^{1} \end{pmatrix} \boldsymbol{\beta} + \begin{pmatrix} \boldsymbol{v}_t^{0} \\ \boldsymbol{v}_t^{1} \end{pmatrix}, \quad (5.7)$$

where $t = 1, \ldots, T$ is an index for the time dimension. The $N \times N$ matrix $\boldsymbol{W}_t$ describing the spatial arrangement of the units in the sample is partitioned into four submatrices: $\boldsymbol{W}_t^{00}$ expresses spatial relations between the units that are in state 0 at the start of period $t$; $\boldsymbol{W}_t^{11}$ between the units that are already in state 1 at the start of $t$; and $\boldsymbol{W}_t^{01}$ and $\boldsymbol{W}_t^{01}$ describe spatial relations of the units in state 0 with the units in state 1 (and vice versa) at the start of period

$t$. Since the number of spatial units in state 0 and 1 may be different from one period to another, these submatrices are time dependent. This is indicated by the subscript $t$.[3]

If observations on units after they transferred to state 1 are removed from the sample, in line with the literature on duration models, only the observations with superscript 0 in the first line of this model remain. If $N_t^0$ denotes the number of observations that are not yet in state 1 at the start of period $t$, the total number of observations to estimate the parameters of this model amounts to $\sum_{t=1}^{T} N_t^0$. Due to the removal of observations that are in state 1, the expected value of the latent variable $\boldsymbol{Y}_t^{1*}$ on the right-hand side is no longer defined. Therefore, we replace the latent variable $\boldsymbol{Y}_t^{1*}$ by the observed variable $\boldsymbol{Z}_t$ which is equivalent to $\boldsymbol{Y}_t^1$. Furthermore, since it is reasonable to assume that neighboring units that already transferred to state 1 have a different impact than neighboring units that are still in state 0, we allow these two variables to have different coefficients $\rho$ and $\delta$. This yields

$$\boldsymbol{Y}_t^{0*} = \rho \boldsymbol{W}_t^{00} \boldsymbol{Y}_t^{0*} + \delta \boldsymbol{W}_t^{01} \boldsymbol{Z}_t + \boldsymbol{X}_t^0 \boldsymbol{\beta} + \boldsymbol{v}_t^0. \tag{5.8}$$

The first variable on the right-hand side, $\boldsymbol{W}_t^{00}\boldsymbol{Y}_t^{0*}$, denotes the endogenous interaction effect with neighboring units that are also in state 0 at the start of period $t$. That is, it includes all neighboring units that will transfer to state 1 during period $t$ as well as units that will not transfer during this period. The second variable on the right-hand side, $\boldsymbol{W}_t^{01}\boldsymbol{Z}_t$, denotes the interaction effect with neighboring units that transferred to state 1 any time before period $t$ (i.e., in periods $t-1, t-2, t-3$, etc.). The first variable, like the dependent variable, is specified in terms of unobserved choices, and the second variable in terms of observed choices. In some studies, there are units that are still in state 0 at the end of the observation period and units that already transferred to state 1 before the start of the observation period. In the first case, the sample is called right-censored; these observations are covered by the first spatial term on the right-hand side of the regression. In

[3] The dimensions of submatrices $\boldsymbol{W}_t^{00}$, $\boldsymbol{W}_t^{01}$, $\boldsymbol{W}_t^{10}$, $\boldsymbol{W}_t^{11}$ are $N_t^0 \times N_t^0$, $N_t^0 \times N_t^1$, $N_t^1 \times N_t^0$ and $N_t^1 \times N_t^1$, respectively, where $N_t = N_t^0 + N_t^1$, for all $t$.

the second case, the sample is called left-censored; these observations are covered by the second spatial term on the right-hand side of the regression.

Units that did not yet transfer may be affected by neighboring units that also did not yet transfer, and vice versa, as a result of which the right-hand side variable $\boldsymbol{W}_t^{00}\boldsymbol{Y}_t^{0*}$, needs to be treated as an endogenous explanatory variable. Units that did not yet transfer may also be affected by neighboring units that already transferred before period $t$ . However, since observations on units in time periods after they transferred to state 1 are removed from the sample, units that did already transfer cannot be affected by units that are still in state 0. Consequently, the right-hand side variable $\boldsymbol{W}_t^{01}\boldsymbol{Z}_t$ is treated as an exogenous rather than an endogenous explanatory variable.[4] Hence, the parameters in Equation (5.8) can be estimated similarly to those of a standard spatial lag probit model, Equation (5.4).

### 5.3.2 Estimation

Based on strengths and weaknesses of different estimation methods discussed in section 2, we use the RIS/GHK-simulator for the normal distribution to obtain ML parameter estimates, described in Vijverberg (1997). For this we need to evaluate an $N$-dimensional integral similar to Equation (5.3). We explain the mechanisms behind the simulator using a simple example. Assume that $N = 3$, $\boldsymbol{Y} = (1,0,1)'$ and that the mean $\boldsymbol{\mu}$ of $\boldsymbol{Y}^*$ corresponds to Equation (5.8) with variance-covariance matrix $\boldsymbol{\Omega}_\rho$, where $\boldsymbol{\Omega}_\rho$ is positive definite. Using the Cholesky decomposition, we can find a lower-triangular matrix $\boldsymbol{Q}$ such that $\boldsymbol{Q}\boldsymbol{Q}' = \boldsymbol{\Omega}_\rho$. Taking $q_{ij}$ as elements of $\boldsymbol{Q}$, we have:

$$
\begin{aligned}
y_1^* &= \mu_1 + q_{11}\nu_1 \geq 0 \\
y_2^* &= \mu_2 + q_{21}\nu_1 + q_{22}\nu_2 \leq 0 \\
y_3^* &= \mu_3 + q_{31}\nu_1 + q_{32}\nu_2 + q_{33}\nu_3 \geq 0.
\end{aligned}
$$

Note that $\nu_1$ follows a standard normal distribution truncated below by

[4] This is the reason why we change the notation from $\boldsymbol{Y}_t^1$ to $\boldsymbol{Z}_t$ in Equation (5.8).

$-\mu_1/q_{11}$. Let $z_1$ be a draw from this distribution.[5] Conditional on $z_1$, $\nu_2$ follows a standard normal distribution truncated above by

$$\frac{-\mu_2 - q_{21}z_1}{q_{22}}.$$

Next, let $z_2$ be a draw from the distribution of $\nu_2$. Finally, conditional on $z_1$ and $z_2$, $\nu_3$ follows a standard normal distribution truncated below by

$$\frac{-\mu_3 - q_{31}z_1 - q_{32}z_2}{q_{33}},$$

and $z_3$ is a draw from this distribution.

Since $z_1$, $z_2$, and $z_3$ are independently distributed, the mean of $\widetilde{p}_r = (1 - \Phi(z_1))\Phi(z_2)(1 - \Phi(z_3))$ is the joint probability that $y_1^* \geq 0$, $y_2^* \leq 0$ and $y_3^* \geq 0$. If we repeat this procedure $R$ times, then

$$\widehat{p} \equiv \frac{1}{R}\sum_{r=1}^{R} \widetilde{p}_r$$

is a consistent estimator of the joint probability, known as the RIS estimator (Vijverberg, 1997; Beron and Vijverberg, 2004). The general form of the RIS simulated likelihood for the $N$-variate case

$$\widehat{p} \equiv \frac{1}{R}\sum_{r=1}^{R} \left\{ \prod_{j=1}^{N} \Phi(z_{j,r}) \right\} \tag{5.9}$$

[5] The procedure of drawing from a truncated standard normal distribution is the following: Let $x \sim \mathcal{N}(0,1)$ and $x > a$. Then the cumulative distribution function (cdf) of $x$ is

$$F(x) = \frac{\Phi(x) - \Phi(a)}{1 - \Phi(a)},$$

where $\Phi(\cdot)$ is the cdf of the standard normal distribution. If $u \sim \mathcal{U}(0,1)$, then we can draw $x$ by solving $u = F(x)$. This leads to:

$$x = \Phi^{-1}(u(1 - \Phi(a)) + \Phi(a)).$$

If $x < a$, then a similar derivation method implies

$$x = \Phi^{-1}((1 - u)\Phi(a)).$$

is used to find the standard maximum-likelihood estimator of $L(\boldsymbol{\beta}, \rho)$

$$L(\boldsymbol{\beta}, \rho) = \int_{\boldsymbol{Y}_t^{0*}} \frac{1}{(2\pi)^{N/2}|\boldsymbol{\Omega}_\rho|^{1/2}} exp\left\{-\frac{1}{2}\boldsymbol{v}'\boldsymbol{\Omega}_\rho^{-1}\boldsymbol{v}\right\} d\boldsymbol{v}, \tag{5.10}$$

by the following optimization

$$\min_{\boldsymbol{\beta},\rho}\{-\log L(\boldsymbol{\beta}, \rho)\}$$

subject to $\rho \in (-1/\omega_{min}, 1)$, where $\omega_{min}$ denotes the smallest characteristic root of $\boldsymbol{W}$. Note that $\delta$ is an element of $\boldsymbol{\beta}$. Finally, we compute the Hessian $\boldsymbol{H}$ of $-\log L(\boldsymbol{\beta}, \rho)$ numerically and calculate standard deviations as the square root of the diagonal elements of $\boldsymbol{H}^{-1}$.

Lee (2004) and Qu and Lee (2012) show that the ML estimator of the spatial lag and the spatial probit model produces consistent and asymptotically normal estimates, provided that several regularity conditions are satisfied (see Elhorst et al. (2013) for a description of regularity conditions).

### 5.3.3 Direct and indirect effects

It is known that the point estimates of the parameter vector $\boldsymbol{\beta}$ in the probit model $\boldsymbol{Y}^* = \boldsymbol{X\beta} + \boldsymbol{v}$ and in the spatial lag model with a continuous dependent variable $\boldsymbol{Y} = \rho\boldsymbol{WY} + \boldsymbol{X\beta} + \boldsymbol{v}$ are not equal to their marginal effects, see respectively Cameron and Trivedi (2005, p. 466) and LeSage and Pace (2009, pp. 293–297). LeSage et al. (2011) consider the marginal effects of the spatial probit model by combining these two models. When applied to our model set forth in Equation (5.8), the matrix of partial derivatives of the expected value of $\boldsymbol{Y}$ with respect to the $k^{th}$ explanatory variable of $\boldsymbol{X}$ in unit 1 up to unit $N$ ($x_{ik}$ for $i = 1, \ldots, N$) at a particular moment in time $t$ takes the form

$$\begin{pmatrix} \frac{\partial E(\boldsymbol{Y}_t)}{\partial x_{1k}} \cdots \frac{\partial E(\boldsymbol{Y}_t)}{\partial x_{Nk}} \end{pmatrix} = \begin{pmatrix} \frac{\partial E(y_{1t})}{\partial x_{1k}} \cdots \frac{\partial E(y_{1t})}{\partial x_{Nk}} \\ \vdots \ddots \vdots \\ \frac{\partial E(y_{Nt})}{\partial x_{1k}} \cdots \frac{\partial E(y_{Nt})}{\partial x_{Nk}} \end{pmatrix} = \text{diag}(\phi(\boldsymbol{\eta}))(\boldsymbol{I} - \rho\boldsymbol{W}_t^{00})^{-1} I_N \beta_k, \tag{5.11}$$

where $\boldsymbol{\eta} = (\boldsymbol{I} - \rho \boldsymbol{W}_t^{00})^{-1}(\delta \boldsymbol{W}_t^{01} \boldsymbol{Z}_t + \boldsymbol{X}_t^0 \boldsymbol{\beta})$ denotes the vector of predicted values of $\boldsymbol{Y}_t^0$.[6]

The first matrix on the right-hand side of this equation is a diagonal matrix of order $N$ whose elements $\phi_i$ represent the probability that the dependent variable takes its observed value, dependent on the observed values of the other units in the sample. For this reason, each observation has its own mean and variance. Define the matrix $\boldsymbol{\Pi}$ as $\boldsymbol{\Pi} = \boldsymbol{\eta}\boldsymbol{\eta}'$, $\pi_{ij}$ as the $(i,j)^{th}$ element of $\boldsymbol{\Pi}$, $\boldsymbol{\Pi}_{-ii}$ as the $(N-1) \times (N-1)$ matrix that is obtained after removing both row and column $i$, and $\boldsymbol{\pi}_{-i}$ as the $i^{th}$ row vector and $\boldsymbol{\pi}_{i-}$ as the $i^{th}$ column vector removed from $\boldsymbol{\Pi}$. Then $\phi_i$ $(i = 1, \ldots, n)$ evaluates the normal probability density function for the observed value of $y_i$, which is either 0 or 1, with mean $\mu_i + \boldsymbol{\pi}_{-i}\boldsymbol{\Pi}_{-ii}^{-1}(y_i - \mu_i)$ and variance $\pi_{ii} - \boldsymbol{\pi}_{-i}\boldsymbol{\Pi}_{-ii}^{-1}\boldsymbol{\pi}_{i-}$.

The second matrix on the right-hand side is an $N \times N$ matrix whose diagonal elements represent the impact on the dependent variable of unit 1 up to $N$ if the $k^{th}$ explanatory variable in the own unit changes, while its off-diagonal elements represent the impact on the dependent variable if the $k^{th}$ explanatory variable in another unit changes. The first is called a *direct effect* and the second an *indirect* or *spatial spillover effect*. Since both the direct and indirect effects are different for different units in the sample, the presentation of these effects is a problem. If we have $N$ spatial units and $K$ explanatory variables, we obtain $K$ different $N \times N$ matrices of direct and indirect effects. LeSage and Pace (2009) therefore propose to report one direct effect measured by the average of the diagonal elements of the matrix on the right-hand side of Equation (5.11), and one indirect effect measured by the average of either the row sums or the column sums of the non-diagonal elements of that matrix. Since the numerical magnitudes of these two calculations of the indirect effect are the same, it does not matter which one is used. Usually, the indirect effect is interpreted as the impact of changing a particular element of an exogenous variable on the dependent variable of all other units, which corresponds to the average column effect. In contrast to LeSage et al. (2011) and other studies in the spatial econometrics literature,

[6] A similar expression applies to the explanatory variable $\boldsymbol{W}_t^{01}\boldsymbol{Z}_t$ with the coefficient $\delta$.

the right-hand side of our model is not independent of time. To obtain one summary indicator for the direct and indirect effects of every explanatory variable in the model, we propose to also average the outcomes over time.

The standard errors and t-values of the direct and indirect effects' estimates are more difficult to determine, because they depend on $\beta_k$, $\rho$ and the elements of the spatial weights matrix $\boldsymbol{W}_t^{00}$ in a rather complicated way. In order to draw inferences regarding the statistical significance of the direct and indirect effects, LeSage and Pace (2009, p. 39) suggest simulating the distribution of the direct and indirect effects using the variance-covariance matrix implied by the maximum likelihood estimates. If the full parameter vector $\boldsymbol{\theta} = (\rho, \delta, \boldsymbol{\beta}')'$ is drawn $D$ times from $N(\hat{\boldsymbol{\theta}}, \mathrm{AsyVar}(\hat{\boldsymbol{\theta}}))$, the standard deviation of each summary indicator can be approximated by the standard deviation of the mean value over these $D$ draws, and the significance by dividing each summary indicator by the estimated corresponding standard deviation.

## 5.4 Data description

We apply our model to the analysis of IT adoption. While Chapter 3 examines the factors leading to IT adoption, this study focuses on spatial interactions between countries in their choice to adopt IT. The research questions are: (i) do endogenous interaction effects influence the probability of countries to adopt IT and (ii) do the explanatory variables of IT adoption cause significant spatial spillover effects?

In our analysis, we assume that in each time period (year) a country can be in one of two possible states: state 1 corresponds to the implementation of IT, while state 0 corresponds to an alternative, non-IT strategy. We are interested in estimating the probability of transition from non-IT to IT, i.e. from state 0 to state 1.

Our panel dataset is the same as in Chapter 3 and consists of 58 countries over the period 1985–2008; coincidentally, 29 countries adopted IT during this period and 29 countries did not (see Table 3.1).[7] We use official adoption dates based on central banks' announcements.

To examine the sensitivity of results to the choice of spatial weights matrices and also to control for different dimensions of proximity between countries (such as institutional, socio-cultural, and geographical proximity), we use three specifications of a spatial weights matrix:

1) **Common legal origin**. An important measure of institutional proximity is common legal tradition. Countries with similar legal origins are stronger connected with each other and more inclined to follow similar policy choices. We adopt the legal similarity weights matrix in which the weights are equal to 1 if countries $i$ and $j$ have the same origin of the legal system, and 0 otherwise. The data on legal systems is based on La Porta et al. (1999) who distinguish English, French, German, Scandinavian, and socialist legal origins.

2) **Common language**. A particular country may be willing to adopt IT if it is implemented by other countries with similar cultural and social background. As a measure of socio-cultural proximity, we use a spatial weights matrix with weights equal to 1 if countries $i$ and $j$ share a common language, and 0 otherwise. Data on countries' official languages are taken from the CIA World Factbook.

3) **Ten-nearest neighbors**. To control for geographical proximity between countries, we adopt the spatial weights matrix in which the elements are equal to 1 if country $j$ belongs to the ten nearest neighbors of country $i$ in the sample, and 0 otherwise.

In all the analyzed spatial weights matrices the diagonal elements are set to zero. The weights matrices are row-normalized before they are split into submatrices. In addition, the submatrix $\boldsymbol{W}_t^{00}$ is row-normalized for every time period.

The matrix $\boldsymbol{X}$ includes six explanatory variables that may affect countries' decision to adopt IT, namely: inflation, output growth, the flexible ex-

[7] In this chapter we exclude Armenia and Sudan from the dataset due to the limited data availability for these two countries.

change rate regime dummy, government debt, financial development and central bank instrument independence. Table B.1 in the Annex describes the explanatory variables and their data sources.[8] The dataset is not complete; the percentage of missing observations on the different explanatory variables ranges from 1% to 13% of all observations. In order to have a complete dataset, an imputation technique is used for filling in missing observations.[9] All explanatory variables are included in the model with a one-year lag, similarly to the approach used in Chapters 3 and 4 of this thesis.

## 5.5 Estimation results

Table 5.1 reports the estimation results. We record the coefficient estimates and their t-statistics for three specifications of the spatial probit model and three spatial weights matrices.

Column (1) of Table 5.1 presents the estimation results for the standard spatial lag probit model when pooling the cross-sectional data over time. This model can be obtained from Equation (5.4) by adding a subscript $t$ ($t = 1, \ldots, T$) to the variables and the error terms of that equation. This model is similar to the one employed in Mukherjee and Singer (2008) for their analysis of IT adoption. We find that the coefficient estimate $\rho$ of the endogenous interaction effects is positive and significant for all spatial weights matrices, while Mukherjee and Singer (2008) report a positive but insignificant result. One explanation is that we use data over a longer time period, 1985–2008 versus 1987–2003 in Mukherjee and Singer (2008). The findings for two variables used in their study and ours — exchange rate regime and central bank independence — are comparable, while the result for inflation is different, both in terms of the sign and significance of the estimate.

[8] Note that in this chapter we use a slightly different definition of financial development, measured as domestic credit provided by the banking sector/GDP. The data for this variable is provided by WDI World Bank. The data for this financial development proxy was available for more countries than for the proxy used in Chapter 3.

[9] We apply the Expectation-Maximization (EM) algorithm for missing values imputation, proposed by Dempster et al. (1977) and described in e.g. Schafer (1997). For the description of the imputation procedure, see Chapter 2, pp. 27-28.

Column (2) shows the estimation results for our spatial probit model with two spatially lagged variables and a full set of regressors. The results suggest that the coefficients of both spatial terms are insignificant for the ten-nearest neighbors' and common language weights matrices, while for the common legal origin matrix the coefficient of the first spatial term ($\rho$) is significant with a positive sign. Note that the value of the log-likelihood is much higher in our specification compared to Column (1).

The estimation of our spatial probit model may also suffer from the potential temporal dependency problem, similar to discrete-time duration models. This means that the probability of a country to adopt IT in year $t$ may depend on the duration of the non-IT period, i.e., the time that has passed from the start of the sample period until the IT adoption date. Ignoring temporal dependence may lead to inefficiency and inaccurate statistical inference (Beck et al., 1998). To correct for temporal dependence, we construct a duration variable that counts the number of years from the start of the sample period until the IT adoption date.[10]

Column (3) reports the estimation results when the duration variable is added as a regressor to our spatial probit model. Importantly, the coefficient estimate of the duration variable turns out to be significant with a positive sign, implying that the longer is the non-IT period, the more likely are countries to adopt IT. Hence, this specification of our spatial probit model is preferred.

The results are sensitive to the choice of a spatial weights matrix. For the common legal origin weights matrix, the coefficient estimate of the endogenous interaction effect in Column (3), $\rho$, is significant with a positive sign. This indicates that countries that adopt IT in the current period have a positive effect on the probability of other countries to take the same decision in that period. Thus, countries follow the IT adoption decisions of countries which are institutionally proximate to them. The coefficient estimate of the spatial interaction effect with countries that already adopted IT before the

[10] Alternatively, one could generate a set of time dummies that mark each non-IT duration period. However, including 24 dummies leads to a substantial loss of degrees of freedom and a substantial increase of computation time.

Table 5.1. **Estimation results - spatial lag probit**

| Variable | (1) Standard spatial probit | | | (2) Our spatial probit | | | (3) ... with duration variable | | |
|---|---|---|---|---|---|---|---|---|---|
| **Common legal origins weights matrix** | | | | | | | | | |
| $\rho$ | 0.482 | (9.86) | *** | 0.262 | (2.00) | ** | 0.471 | (5.41) | *** |
| $\delta$ | | | | 0.391 | (0.90) | | −0.532 | (−0.93) | |
| Inflation | −6.033 | (−6.58) | *** | −3.153 | (−2.23) | ** | −1.167 | (−1.27) | |
| Output growth | 0.010 | (0.63) | | −0.067 | (−2.50) | ** | −0.040 | (−1.68) | * |
| Flexible exchange rate regime | 0.879 | (8.18) | *** | 0.798 | (4.23) | *** | 0.677 | (3.61) | *** |
| Government debt | 0.0001 | (0.07) | | −0.005 | (−1.48) | | −0.005 | (−1.45) | |
| Financial development | −0.228 | (−2.90) | *** | −0.481 | (−2.57) | ** | −0.275 | (−1.63) | |
| Central bank instrument independence | 1.028 | (10.19) | *** | 0.435 | (2.39) | ** | 0.141 | (0.71) | |
| Constant | −0.094 | (−13.49) | *** | −0.898 | (−2.45) | ** | −1.042 | (−3.11) | *** |
| Duration of non-IT period | | | | | | | 0.042 | (2.14) | ** |
| Log-likelihood | -366.20 | | | -110.97 | | | -110.49 | | |
| **Common language weights matrix** | | | | | | | | | |
| $\rho$ | 0.196 | (2.82) | *** | 0.116 | (1.25) | | −0.036 | (−0.37) | |
| $\delta$ | | | | −0.186 | (−0.41) | | −1.351 | (−1.99) | ** |
| Inflation | −7.433 | (−7.59) | *** | −3.613 | (−2.51) | ** | −3.816 | (−2.78) | *** |
| Output growth | 0.001 | (0.05) | | −0.063 | (−2.44) | ** | −0.097 | (−3.51) | *** |
| Flexible exchange rate regime | 0.887 | (8.12) | *** | 0.804 | (4.19) | *** | 0.893 | (4.45) | *** |
| Government debt | −0.002 | (−1.13) | | −0.003 | (−1.03) | | −0.006 | (−1.71) | * |
| Financial development | −0.274 | (−3.29) | *** | −0.469 | (−2.41) | ** | −0.515 | (−2.65) | *** |
| Central bank instrument independence | 0.916 | (9.31) | *** | 0.373 | (2.06) | ** | 0.066 | (0.32) | |
| Constant | −0.103 | (−13.14) | *** | −1.185 | (−3.80) | *** | −1.729 | (−4.73) | *** |
| Duration of non-IT period | | | | | | | 0.077 | (3.32) | *** |
| Log-likelihood | -391.55 | | | -112.86 | | | -106.86 | | |
| **Ten-nearest neighbors' weights matrix** | | | | | | | | | |
| $\rho$ | 0.123 | (1.68) | * | 0.024 | (0.19) | | −0.092 | (−0.71) | |
| $\delta$ | | | | 0.041 | (0.09) | | −0.689 | (−1.16) | |
| Inflation | −7.289 | (−7.46) | *** | −3.583 | (−2.35) | ** | −4.179 | (−2.33) | ** |
| Output growth | −0.002 | (−0.10) | | −0.065 | (−2.48) | ** | −0.078 | (−2.76) | *** |
| Flexible exchange rate regime | 0.838 | (7.86) | *** | 0.729 | (3.96) | *** | 0.802 | (4.16) | *** |
| Government debt | −0.002 | (−1.35) | | −0.005 | (−1.50) | | −0.005 | (−1.69) | * |
| Financial development | −0.254 | (−3.02) | *** | −0.476 | (−2.35) | ** | −0.377 | (−1.94) | * |
| Central bank instrument independence | 0.941 | (9.47) | *** | 0.347 | (1.80) | * | 0.217 | (1.09) | |
| Constant | −0.102 | (−12.71) | *** | −1.205 | (−3.36) | *** | −2.057 | (−4.62) | *** |
| Duration of non-IT period | | | | | | | 0.070 | (2.85) | *** |
| Log-likelihood | -394.15 | | | -113.83 | | | -107.59 | | |
| Observations | 1334 | | | 1069 | | | 1069 | | |

*Notes:* This table reports coefficient estimates and their t-values (in parentheses). ***, ** and * denote significance at the 1%, 5% and 10% significance level, respectively. Column (1) shows the results for a standard spatial lag probit model, column (2) for our spatial probit model, while column (3) extends the model by controlling for temporal dependence.

current period ($\delta$) is insignificant with a negative sign.

For the common language weights matrix $\rho$ is insignificant, but $\delta$ becomes significant with a negative sign in the model with the duration variable. There are several explanations for this negative spatial interaction effect. An intuitive explanation for the negative sign of $\delta$ is that more countries adopt IT as time elapses, as a result of which there are less countries in the sample left that did not transfer yet. Therefore, over time the probability to adopt IT becomes lower as the number of neighboring (culturally proximate) countries that can decide to switch, diminishes. Another explanation is that the explanatory variables of countries that did and did not yet adopt IT take different values and are treated differently. Whereas the explanatory variables are part of the model for the latter group of countries, they are not for the former group since observations on these countries are removed from the sample after adoption. Consequently, the impact these countries have on countries that are still considering IT only runs through the spatial interaction coefficient, which therefore also captures the effect of any value changes in these explanatory variables.

For the ten-nearest neighbors' weights matrix, both spatial interaction effects are insignificant. Apparently, geographical distance does not play a role when we analyze spatial interactions between countries in their monetary strategy choice. This also follows from the year when different countries adopted IT. For instance, countries that adopted IT in 2001, namely Hungary, Iceland, Mexico, and Norway, are anything but close neighbors to each other. Conversely, countries that are close neighbors to each other, like the Czech Republic, Poland, Hungary, Slovakia, and Romania, adopted IT in various years (see Table 3.1). Thus, in the analysis of spatial interdependence between countries, non-geographical measures of proximity could be more useful in explaining why countries interact with each other.

Additionally, we find that countries with lower inflation, lower output growth, more flexible exchange rate regimes, and lower government debt are more likely to adopt IT. Financial system development has a negative and significant (in most of estimated models) impact on the probability to adopt IT, while the estimate for central bank instrument independence is significant with a positive sign (except for models with the duration variable). It should be noted that differences between these variables in the pre- and post-adoption periods affect the magnitude of the spatial interaction coefficient too, which therefore should be interpreted as the net effect of all value changes in all explanatory variables between these two periods.

### Direct and indirect effects

Table 5.2 shows the effects of changes in explanatory variables on the probability of a particular country to adopt IT (direct effects), as well as the spatial spillover effects of explanatory variables on neighboring (proximate) countries (indirect effects) and the sum (total effects) for the three models of Table 5.1. We calculate these effects for the models using a spatial weights matrix based on common legal origins since for this matrix the estimate of $\rho$ is significant.

Four explanatory variables produce significant direct and indirect effects in the standard spatial probit model (inflation, exchange rate regime, financial development, and central bank instrument independence). In our spatial model specifications several direct effects are significant. The spatial probit model (2) shows no signs of spatial spillover effects. However, including a duration variable in our model (3) leads to the significance of indirect effects for three variables — exchange rate regime, duration of non-IT period and number of countries that already adopted IT ($\boldsymbol{Z_t}$). Thus, the fewer countries have already adopted IT, the longer is the non-IT period and the more flexible is the exchange rate regime of a particular country, the higher is the probability of other (proximate) countries to adopt IT.

Importantly, direct and indirect effects of inflation in model (1) are larger in size than their counterparts in models (2) and (3). These results are in line with Chapter 4, which also shows that the marginal effect of inflation on the probability of IT adoption is largely overestimated in the model including the post-adoption period compared to the one without this period. The standard spatial probit model (1), similarly to the restricted model in

Table 5.2. **Direct, indirect and total effects for common legal origins matrix**

| Variables | Direct effects | Indirect effects ($\times 10^{-2}$) | Total effects |
|---|---|---|---|
| (1) *Standard spatial probit* | | | |
| Inflation | −1.177 *** | −1.296 *** | −1.190 *** |
| | (−8.25) | (−6.60) | (−8.26) |
| Output growth | 0.002 | 0.002 | 0.002 |
| | (0.77) | (0.75) | (0.77) |
| Flexible exchange rate regime | 0.168 *** | 0.187 *** | 0.170 *** |
| | (7.58) | (5.03) | (7.55) |
| Government debt | 0.000 | 0.000 | 0.000 |
| | (−0.08) | (−0.06) | (−0.08) |
| Financial development | −0.043 *** | −0.048 *** | −0.044 *** |
| | (−3.11) | (−2.79) | (−3.11) |
| Central bank instrument independence | 0.198 *** | 0.220 *** | 0.200 *** |
| | (9.88) | (5.01) | (9.79) |
| (2) *Our spatial probit* | | | |
| Countries that already adopted IT ($\boldsymbol{Z}_t$) | −0.103 ** | −0.054 | −0.103 ** |
| | (−2.40) | (−1.55) | (−2.40) |
| Inflation | −0.391 * | −0.220 | −0.393 * |
| | (−1.84) | (−1.23) | (−1.83) |
| Output growth | −0.008 ** | −0.005 | −0.009 ** |
| | (−2.22) | (−1.29) | (−2.21) |
| Flexible exchange rate regime | 0.105 ** | 0.061 | 0.106 ** |
| | (2.54) | (1.34) | (2.52) |
| Government debt | −0.001 | 0.000 | −0.001 |
| | (−1.41) | (−1.04) | (−1.40) |
| Financial development | −0.062 ** | −0.035 | −0.062 ** |
| | (−2.09) | (−1.32) | (−2.08) |
| Central bank instrument independence | 0.057 * | 0.032 | 0.057 * |
| | (1.82) | (1.25) | (1.82) |
| (3) *Our spatial probit with a duration variable* | | | |
| Countries that already adopted IT ($\boldsymbol{Z}_t$) | −0.251 *** | −0.205 ** | −0.253 *** |
| | (−3.01) | (−2.47) | (−3.01) |
| Inflation | −0.249 | −0.199 | −0.251 |
| | (−1.19) | (−1.09) | (−1.19) |
| Output growth | −0.009 * | −0.007 | −0.009 * |
| | (−1.85) | (−1.62) | (−1.85) |
| Flexible exchange rate regime | 0.159 *** | 0.133 ** | 0.161 *** |
| | (3.23) | (2.42) | (3.22) |
| Government debt | −0.001 | 0.000 | −0.001 |
| | (−1.30) | (−1.18) | (−1.29) |
| Financial development | −0.058 | −0.049 | −0.059 |
| | (−1.41) | (−1.29) | (−1.41) |
| Central bank instrument independence | 0.036 | 0.031 | 0.036 |
| | (0.91) | (0.85) | (0.91) |
| Duration of non-IT period | 0.010 ** | 0.008 * | 0.010 ** |
| | (1.88) | (0.50) | (1.61) |

*Notes:* This table reports direct, indirect, and total effects with t-values (in parentheses) for models (1), (2), and (3) as in Table 5.1. ***, ** and * denote significance at the 1%, 5% and 10% significance level, respectively.

Chapter 4, uses the full sample for the analysis and retains observations on countries after IT adoption. The estimated direct effect of inflation in model (1) is equal to -1.18. Meanwhile, in our spatial probit models (2) and (3) we remove observations on countries after they adopt IT. It leads to a drop in the size of the direct effect of inflation to -0.10 in model (2) and -0.25 in model (3). These results are consistent with the findings in Chapters 3 and 4.[11]

Note that we report the direct and indirect effects on the probability to adopt IT, i.e. $Pr(y_{it} = 1)$. Once we consider the willingness to adopt IT, represented by the latent variable $y^*_{it}$, instead of the probability, the newly calculated direct and especially spatial spillover effects become much larger in absolute values. Thus, the impact of changes in explanatory variables on the willingness of a particular country as well as other countries to adopt IT is stronger than the impact on their probability to adopt. These results are available on request.

## 5.6 Conclusion

The analysis of spatial interactions between countries in their choice to adopt IT has not received much attention in the literature. This chapter adds the spatial econometric aspect into the empirical investigation of IT adoption. We propose a novel approach to the analysis of spatial interdependence by developing a spatial probit model with two spatially lagged variables, one for countries that did not adopt IT yet, and one for countries that already adopted it. The empirical model is estimated by maximum likelihood methods, using the Recursive-Importance-Sampling simulator to evaluate the truncated multidimensional normal distribution.

The outcomes are sensitive to the choice of the spatial weights matrix. Most notably, we find that countries that adopt IT in the current period increase the probability of other countries with similar legal origins to adopt it as well. Thus, the endogenous interaction effects are found significant.

[11] Note that in Chapters 3 and 4 the estimated effect of inflation is between -0.30 and -0.50. The differences in the size could be due to the fact that in this chapter we use a modified dataset of Chapter 3 and include only six explanatory variables.

Meanwhile, for the common language weights matrix, the results suggest that countries that already adopted IT before the current period have a significant negative effect on others to adopt. In addition, we find several significant direct and indirect effects in our model specifications. The latter implies that the explanatory variables for a particular country have a significant spillover effect on the probability of other countries to adopt IT.

*Chapter 6*

# Inflation targeting and inflation performance*

## 6.1 Introduction

Twenty years after New Zealand adopted inflation targeting (IT), its pros and cons are still discussed in the economic literature (Roger, 2009; Walsh, 2009; De Carvalho Filho, 2010). Proponents of IT consider it an attractive monetary strategy, arguing that it will lead to lower and less variable inflation and will increase the credibility of the central bank. These alleged benefits have been examined in several studies, often concluding that IT countries experienced a larger decrease in inflation than non-IT countries. However, Ball and Sheridan (2004) argue that these studies suffer from an endogeneity bias, as countries struggling with high inflation are far more likely to adopt IT. Controlling for this regression-to-the-mean effect, Ball and Sheridan (2004) conclude that the adoption of IT has no impact on inflation in their sample of advanced countries. In an update of this research, Ball (2010) finds a significant but small effect, while Mishkin and Schmidt-Hebbel (2007) and Willard (2012) do not find a significant impact of IT on inflation.

Some recent studies focusing on emerging countries report a significant effect of IT on inflation. Gemayel et al. (2011), for example, conclude that

* This chapter is based upon Samarina et al. (2014).

IT reduces inflation in low-income economies. Gonçalves and Salles (2008) and De Mendonça and de Guimarães e Souza (2012) report similar results for a set of emerging and developing countries. In short, the literature has not reached a consensus on the effect of IT on macroeconomic performance. Additionally, it is difficult to compare the results between the studies as each uses different country samples, time periods, IT adoption dates, and methodologies.

The purpose of this chapter is to examine to what extent results of previous studies are driven by particular choices that have to be made in this line of empirical research, such as the sample of countries, IT adoption date, estimation period and methodology applied, in order to test the robustness of these results. This study adds to the existing literature by providing a comprehensive robustness analysis of IT effects on inflation performance. Specifically, we examine how the sample composition, the estimation period, and the dating of IT introduction influence the results of this research. Moreover, to explore whether conclusions depend on the choice of a particular methodological approach, we apply two completely different estimation techniques, which have been widely used in previous studies, namely the difference-in-differences method and propensity score matching. Our sample consists of 25 advanced and 59 emerging and developing countries over the period 1985–2011.

Our findings suggest that distinguishing countries by economic development is crucial, as no effect of IT is found for advanced countries, whereas the results indicate a significant impact of IT on inflation reduction in emerging and developing countries. Moreover, our results are robust to the choice of the econometric method.

The rest of the chapter is organized as follows. Section 6.2 offers a literature review, while sections 6.3 and 6.4 describe the methodology and data, respectively. Section 6.5 presents the empirical results and section 6.6 concludes.

## 6.2 Literature review

Countries that adopted IT generally saw their inflation decline. However, previous research has not led to a consensus on whether this lower inflation is due to IT or external factors. For instance, the global trend of decreasing inflation may be responsible for most of the decline in inflation in IT countries. Apart from some case studies, most previous studies on IT effects have used three econometric methods, namely: a difference-in-differences approach, a propensity score matching method, and panel estimations.

Early studies adopting a difference-in-differences approach, such as Neumann and von Hagen (2002), found that IT reduced the mean and the variance of inflation. However, these studies ignored the possibility of endogeneity: the initial level of inflation affects the likelihood that a country will adopt IT. Hence, research that does not test for these initial conditions is likely to produce biased results. Ball and Sheridan (2004) were the first to tackle this problem by adding initial conditions as an explanatory variable. This led to very different results: the initial level of inflation explains most of the decline of inflation, while IT has no additional significant effect. In an update of this research, Ball (2010) finds that IT results in a significant reduction in inflation, but the effect is relatively small.

Vega and Winkelried (2005), Lin and Ye (2007), and De Mendonça and de Guimarães e Souza (2012) solve the endogeneity issue in a different way by applying the propensity score matching method. This method compares countries that had similar initial conditions whereas one adopted IT and the other did not. Lin and Ye (2007) and De Mendonça and de Guimarães e Souza (2012) find no significant effect of IT on inflation in advanced countries, but using a larger and more diverse sample Vega and Winkelried (2005) report opposite results.

Finally, some studies based on panel estimations conclude that although IT countries have lower inflation and output volatility after their change of monetary policy strategy, they have not performed better than non-inflation targeters (Mishkin and Schmidt-Hebbel, 2007; Willard, 2012).

Although most findings of the studies discussed above are not supportive of IT, it is important to note that these studies focus on advanced countries. More recent studies recognize this and perform similar analyses on a sample of emerging economies. Batini and Laxton (2006) report that IT has a significant effect on the fall of inflation, but they make the caveat that only a short time has elapsed since the implementation of IT in most emerging economies. Mishkin and Schmidt-Hebbel (2007) also include emerging and developing economies in their sample and find no effect of IT when they compare IT countries with a sample of non-IT OECD countries. The authors argue that this makes their results more stringent as their control group is at the ”international frontier of macroeconomic management and performance” (Mishkin and Schmidt-Hebbel, 2007, p. 4) and it will raise the stakes against IT. More recently, Gonçalves and Salles (2008) apply a difference-in-differences analysis to a larger sample of emerging economies; their results show a significant effect of IT on the decline of inflation as well as its volatility. However, Ball (2010) criticizes this study by questioning the dating of IT adoption, the range of time series used, and the way periods of hyperinflation are treated.

Lin and Ye (2009) and De Mendonça and de Guimarães e Souza (2012) use propensity score matching and find strong evidence that IT reduces inflation and its volatility in emerging and developing countries. Finally, Gemayel et al. (2011) examine the performance of IT for low-income countries; they find a significant impact of IT on inflation decrease. However, as they admit themselves, the sample of low-income countries is too small to draw reliable conclusions, as only Ghana and Armenia adopted IT, while Albania, Moldova, and Georgia are moving towards it. Unlike other studies, Brito and Bystedt (2010) apply a different technique — a dynamic panel estimator — and find that IT reduces inflation in emerging economies, but this result is not robust to the variations in the control group.

It is worth mentioning that all the discussed studies have one common shortcoming, namely treating IT choice as binary. That is, they assume that countries either adopt IT or do not adopt IT; hence, they do not distinguish

Table 6.1. **Empirical studies of IT effects on inflation**

| Study | Countries (IT countries) | Time period | Method | Result |
|---|---|---|---|---|
| **Studies that include advanced as well as emerging and developing countries** | | | | |
| Vega and Winkelried (2005) | 109 (23) | 1990-2004 | propensity score matching | negative[a] |
| Mishkin and Schmidt-Hebbel (2007) | 34 (21) | 1989-2004 | difference-in-differences, panel estimations | no effect (for advanced), negative (for emerging and developing) |
| De Mendonça and de Guimarães e Souza (2012) | 180 (29) | 1990-2007 | propensity score matching | no effect (for advanced), negative (for emerging and developing) |
| **Studies that include only advanced countries** | | | | |
| Neumann and von Hagen (2002)[b] | 9 (6) | 1978-2001 | difference-in-differences | negative |
| Ball and Sheridan (2004) | 20 (7) | 1985-2001 | difference-in-differences | no effect |
| Lin and Ye (2007) | 22 (7) | 1985-1999 | propensity score matching | no effect |
| Ball (2010) | 20 (9) | 1985-2007 | difference-in-differences | very small negative effect |
| Willard (2012) | 21 (8) | 1985-2002 | panel estimations | no effect |
| **Studies that include only emerging and developing countries** | | | | |
| Batini and Laxton (2006) | 44 (13) | 1985-2004 | difference-in-differences | negative |
| Gonçalves and Salles (2008) | 36 (13) | 1980-2005 | difference-in-differences | negative |
| Lin and Ye (2009) | 52 (13) | 1985-2004 | propensity score matching | negative |
| Brito and Bystedt (2010) | 46 (13) | 1980-2006 | dynamic panel model | negative |
| Gemayel et al. (2011)[c] | 57 (10) | 1990-2008 | difference-in-differences, panel estimations | negative |

*Notes:* [a] A negative effect on inflation means that IT implementation significantly reduces the inflation level.
[b] Neumann and von Hagen (2002) do not take the initial level of inflation into account.
[c] Emerging countries are used as a proxy for the small set of low-income countries.

between differences in IT regimes based on the number of targets, the central bank's objectives or transparency in communication of monetary strategy. Unfortunately, so far there is no comprehensive IT index for all IT countries available in the literature that would differentiate between IT regimes based on various criteria.[1] This remains a task for future research.

To conclude, as summarized in Table 6.1, recent empirical studies find very contrasting results regarding the effects of IT on inflation performance. Blinder et al. (2008) point out that the selection of the control group is of utmost importance in this line of research. Unfortunately, not all studies take this issue carefully into account. Previous research is also inconsistent in selecting the adoption dates of IT and often does not examine whether the choice of a particular date affects the outcomes. Nor do previous studies investigate to what extent results are driven by the choice of a particular method, notably difference-in-differences versus propensity scoring. This chapter aims to improve upon these shortcomings. In contrast to previous studies, we also include the years of the Global Financial Crisis (2008–2010), when central banks focused on saving financial systems and were less concerned about inflation.

## 6.3 Methodology

### 6.3.1 Difference-in-differences method

Our first estimation technique is the difference-in-differences method. Following Ball and Sheridan (2004), initial inflation is included as an explanatory variable to take regression-to-the-mean into account. Regression-to-the-mean happens if poorly performing countries converge to the mean performance regardless of the implemented policies. At the same time, poor

[1] Note that the use of a complex IT index would require a modification of the estimation techniques (such as propensity score matching and difference-in-differences method) to allow for a multinomial IT variable instead of a dummy, which is quite difficult. This could explain why a non-binary IT variable has not been used so far in the analysis of IT effects. We follow previous studies and use an IT dummy. By examining to what extent issues such as adoption date affect the results we hope to capture at least to some extent that IT is more complex than a binary state of the world.

performers are also more motivated to adopt new monetary policy strategies in order to improve their inflation performance, resulting in biased estimates. This might occur in our analysis, since the sample of non-inflation targeters has a higher mean inflation rate before adoption than the sample of inflation targeters. We take this into account and estimate the following equation:[2]

$$(\pi_{i,post} - \pi_{i,pre}) = \alpha + \beta_1 \pi_{i,pre} + \beta_2 IT_i + \varepsilon_i; \quad i = 1, \ldots, N, \tag{6.1}$$

where $\pi_{i,pre}$ denotes average inflation of country $i$ in the period before IT adoption, while $\pi_{i,post}$ is average inflation in the post-adoption period. The left-hand side of Equation (6.1) shows the change in inflation between the periods after IT adoption and before adoption; $\alpha$ is a constant term; $\beta_1$ and $\beta_2$ are parameters to be estimated; $IT_i$ is a dummy variable which takes the value 1 if country $i$ adopted IT, and 0 otherwise. If IT adoption leads to lower inflation, $\beta_2$ is negative. To control for regression-to-the-mean, we include initial inflation $\pi_{i,pre}$ as an independent variable. Finally, $\varepsilon_i$ is an error term with mean zero and variance $\sigma_\varepsilon^2$. The model is estimated using OLS for cross-sectional data.

### 6.3.2 Propensity Score Matching method

The difference-in-differences technique has some important drawbacks. First, it does not deal with selection bias, which appears due to the arbitrary choice of countries for the control group of non-IT countries (De Mendonça and de Guimarães e Souza, 2012). Another important issue is endogeneity of IT choice. The decision of countries to adopt IT is not exogenous but is driven by various macroeconomic, financial, institutional, and other factors. Moreover, self-selection of IT adoption may lead to wrong conclusions about the actual effects of IT on inflation. For instance, in Chapter 3 we find that countries with lower past inflation are more likely to adopt IT. Not surprisingly, it could be found that inflation targeters have lower inflation after

[2] See Batini and Laxton (2006) for more details about the model.

adoption than non-inflation targeters. To deal with the self-selection problem and endogeneity of IT, we apply the Propensity Score Matching (PSM) framework, which has been used by Vega and Winkelried (2005), Lin and Ye (2007, 2009), and De Mendonça and de Guimarães e Souza (2012).

The PSM technique involves a two-step procedure.[3] First, we estimate the propensity score, which measures the conditional probability to adopt IT given countries' pre-adoption characteristics. This probability is specified as follows:

$$p(\boldsymbol{X}) = Pr(\boldsymbol{D} = 1|\boldsymbol{X}) = E(\boldsymbol{D}|\boldsymbol{X}), \tag{6.2}$$

where $\boldsymbol{D} = \{0, 1\}$ is a treatment (IT) dummy that takes value 1 if a country chooses IT, and 0 otherwise; $\boldsymbol{X}$ is a matrix of the pre-adoption characteristics. Propensity scores can be estimated by any probability model. We use the logit model as it fits the data better than the probit model. Following previous studies (Lin and Ye, 2009; De Mendonça and de Guimarães e Souza, 2012), we choose such variables for the $\boldsymbol{X}$ matrix that satisfy the following conditions: (i) they characterize the state of the country's economy, (ii) they may drive the decision to adopt IT, and (iii) they may influence average inflation.

Second, once the propensity score $p(\boldsymbol{X})$ is known, the average effect of treatment on the treated (ATT) is estimated as in Equation (6.3):

$$\begin{aligned} ATT &\equiv E\{Y_{1i} - Y_{0i}|D_i = 1\} \\ &= E[E\{Y_{1i}|D_i = 1, p(X_i)\} - E\{Y_{0i}|D_i = 0, p(X_i)\}|D_i = 1], \end{aligned} \tag{6.3}$$

where $\boldsymbol{Y}_1$ and $\boldsymbol{Y}_0$ are potential inflation outcomes in two counterfactual situations: with the treatment (IT applied) and without (IT not applied), respectively. In order to evaluate Equation (6.3) given Equation (6.2), two conditions need to be satisfied:

I. The Balancing Hypothesis: observations with the same propensity score should have the same distribution of observable (and unobservable) charac-

[3] The PSM methodology employed in this paper is based on the description of Becker and Ichino (2002), Dehejia and Wahba (2002), and De Mendonça and de Guimarães e Souza (2012).

teristics independently of the treatment status: $\boldsymbol{D} \perp \boldsymbol{X}|p(\boldsymbol{X})$ . To test the Balancing Hypothesis we apply the following algorithm of Becker and Ichino (2002) and Dehejia and Wahba (2002):

1. Fit the logit (probit) model with a parsimonious specification that includes all covariates as linear terms.
2. Split the sample into $k$ equally spaced intervals of the propensity score.
3. Within each interval, test whether the means of covariates do not differ significantly between treated and control units.
4. If the means of all covariates do not differ, the balancing property is satisfied.
5. If the means of one or more covariates differ for some interval, divide the interval into finer ones and re-evaluate.
6. If the means differ for many intervals, modify the model specification by adding interaction terms and/or higher-order terms of covariates and re-evaluate.
7. Repeat the algorithm until the balancing property is satisfied.

II. The Unconfoundedness Hypothesis: assume that the assignment to treatment is unconfounded, such that: $\boldsymbol{Y}_1, \boldsymbol{Y}_0 \perp \boldsymbol{D}|\boldsymbol{X}$. Then, it implies that $\boldsymbol{Y}_1, \boldsymbol{Y}_0 \perp \boldsymbol{D}|p(\boldsymbol{X})$.[4]

To calculate the ATTs, we use the estimated propensity scores to match the units from the treatment group (inflation targeters) with the most suitable units from the control group (non-inflation targeters) based on different matching criteria. We apply four matching methods suggested in the literature: nearest-neighbor matching, radius matching, kernel matching, and stratification matching (for details see Becker and Ichino (2002)). To test sensitivity of the results, in radius matching we use three different radius distances (r = 0.005; 0.02; 0.04), while in kernel matching the Gaussian and Epanechnikov kernel functions are applied. Standard errors for the ATTs are

[4] The Unconfoundedness Hypothesis cannot be tested.

obtained by bootstrapping (see De Mendonça and de Guimarães e Souza (2012) for a description of the bootstrapping procedure). [5]

## 6.4 Data description

### 6.4.1 Country sample

Our dataset consists of 84 countries over the period 1985–2011, out of which 29 adopted IT during the period analyzed (the treatment group), while 55 countries did not adopt IT (the control group). Following the IMF classification, our sample contains 25 advanced and 59 emerging and developing countries (see Table C.1 in the Annex for details)

The control group of non-inflation targeters is selected in the following way. In the subsample of advanced countries we include 12 inflation targeters, matched with 13 advanced non-inflation targeters, using OECD membership as a criterion. In the subsample of emerging and developing countries we include 17 inflation targeters. Following the approach of Rose (2007) and Lin and Ye (2009), the control group for this subsample consists of 42 emerging and developing countries that have a population at least as large as the population of the smallest IT country, and/or GDP per capita at least as high as GDP per capita of the poorest inflation targeter in this subsample.

### 6.4.2 Data: Difference-in-differences method

For the difference-in-differences method we use quarterly observations starting from the first quarter of 1985 until the last quarter of 2011. To measure

[5] The third possible estimation technique is a dynamic panel model. However, it has been rarely used in previous studies on the IT impact on inflation for several reasons. First, similar to the difference-in-differences method, dynamic panel models do not address the problem of self-selection of countries adopting IT as well as the arbitrary choice of non-IT countries. Second, there are serious estimation issues in such models that are nontrivial to be solved, such as the initial conditions problem, serial correlation in error terms, and selection of valid, non-redundant instruments for model identification (Baltagi, 2008, Chapter 8). For these reasons we do not apply dynamic panel models in this analysis.

inflation, we use quarterly data on annualized CPI inflation rate from the International Financial Statistics IMF database. Average inflation for the pre-adoption period is calculated as the mean inflation from the start of the analyzed period until (and including) the last quarter before IT adoption. Average inflation for the post-adoption period is calculated as the mean inflation starting from the first quarter of IT adoption until the end of the sample period.

There is no agreement in the literature on the exact adoption dates of IT. De Mendonça and de Guimarães e Souza (2012) provide an up-to-date comparison of different adoption dates, mentioned in studies on IT. Authors use different criteria for pinpointing the start of IT. For instance, Mishkin and Schmidt-Hebbel (2007) consider a country as an inflation targeter when the inflation target is being gradually reduced towards a fixed, stationary level, while Batini and Laxton (2006) recognize a country as an inflation targeter when inflation is the single nominal anchor for monetary policy. Ball and Sheridan (2004) claim that the choice of adoption dates does not influence their results on the impact of IT on inflation. However, they do not provide detailed results.

To test whether the effects of IT on inflation depend on the selection of adoption dates, both for advanced and emerging and developing countries, we use two different dates: 'loose' and 'strict' adoption dates. 'Loose' dates are the earliest known adoption dates, which often correspond to soft IT, when countries simply announce inflation targets without strong commitment to achieving them and use simultaneously other nominal anchors. 'Strict' dates correspond to the latest known adoption dates of 'stable' IT, when a central bank uses a single, inflation target in monetary policy and is credibly committed to reaching the target. Table 6.2 shows the adoption dates used in this study. For some countries, the difference between both dates is substantial.

In order to compare the performance of inflation targeters with non-inflation targeters before and after the adoption, we need to select a 'cut-off date' for non-inflation targeters. Most of studies solve this problem by

Table 6.2. **Adoption dates of IT**

| Advanced countries | | | Emerging and developing countries | | |
|---|---|---|---|---|---|
| Countries | Loose IT | Strict IT | Countries | Loose IT | Strict IT |
| Australia | 1993q1 | 1994q4 | Brazil | 1999q1 | 1999q3 |
| Canada | 1991q1 | 1995q1 | Chile | 1991q1 | 2001q1 |
| Finland | 1993q1 | 1994q1 | Colombia | 1991q1 | 1999q4 |
| Iceland | 2001q1 | 2003q1 | Czech Republic | 1998q1 | 1998q1 |
| Israel | 1992q1 | 1997q2 | Ghana | 2007q2 | 2007q2 |
| Korea | 1998q1 | 2001q1 | Guatemala | 2005q1 | 2005q1 |
| New Zealand | 1990q1 | 1993q1 | Hungary | 2001q1 | 2001q3 |
| Norway | 2001q1 | 2001q1 | Indonesia | 2005q1 | 2006q1 |
| Spain | 1994q1 | 1995q2 | Mexico | 1999q1 | 2001q1 |
| Sweden | 1993q1 | 1995q1 | Peru | 1994q1 | 2002q1 |
| Switzerland | 2000q1 | 2000q1 | Philippines | 2001q1 | 2002q1 |
| United Kingdom | 1992q1 | 1993q1 | Poland | 1998q1 | 1999q1 |
| | | | Romania | 2005q3 | 2005q3 |
| | | | Slovakia | 2005q1 | 2005q1 |
| | | | South Africa | 2000q1 | 2001q1 |
| | | | Thailand | 2000q1 | 2000q2 |
| | | | Turkey | 2002q1 | 2006q1 |
| **Average** | **1994q4** | **1996q4** | **Average** | **2000q1** | **2002q2** |

*Notes:* Finland, Spain, and Slovakia abandoned IT after they adopted the euro in 1999, 1999, and 2009, respectively.

Sources: Ball (2010), Gemayel et al. (2011), De Mendonça and de Guimarães e Souza (2012).

calculating the average adoption date for inflation targeters and use it as the benchmark adoption date for non-inflation targeters. In this chapter we apply a similar approach. We divide the sample into advanced, and emerging and developing economies, since we conduct estimations separately for these subsamples. For advanced countries the 'loose' benchmark adoption date is the fourth quarter of 1994 and the 'strict' date is the fourth quarter of 1996. For emerging and developing economies the respective benchmark dates are the first quarter of 2000 and the second quarter of 2002.

We need to select a long time period to calculate the average inflation before IT adoption and compare it with inflation for a similarly long period after the adoption. The range of observations varies greatly in existing literature. Studies use time series that start in 1980, 1985 or 1990 (see Table 6.1). Research focusing on advanced countries commonly uses earlier starting dates than studies on emerging and developing economies, since advanced countries adopted IT earlier than emerging and developing ones. To test for the sensitivity of using different time horizons, we use two periods for each subsample: observations starting in 1985 and 1990 for advanced countries and observations starting in 1990 and 1996 for emerging and developing countries.

### 6.4.3 Data: PSM method

For the PSM estimation, we use annual observations over 1985–2011. The outcome variable is measured as the annual CPI inflation rate, from the IMF's International Financial Statistics. For IT adoption dates, we refer to Table 6.2 and use the 'half-year rule': if IT is adopted in the first or second quarter of year $t$, the adoption year is $t$, if adopted in the third or fourth quarter — the adoption year is $(t+1)$.

Based on previous studies that analyze the probability to adopt IT and its effects on inflation (Lin and Ye, 2009; De Mendonça and de Guimarães e Souza, 2012; Samarina and de Haan, 2014), we select the following variables that may drive IT choice: (1) one-year lagged CPI inflation rate[6]; (2) log of real GDP per capita, in 2000 USD; (3) exchange rate regime indicator (ranges between 1 and 15, higher values indicate more flexible exchange rates); (4) broad money growth; (5) financial development (proxied as credit by banking sector to GDP); (6) government debt as percentage of GDP; (7) trade openness (measured as export plus import as percentage of GDP); and (8) financial openness (Chinn-Ito index of capital account liberalization). The expected signs and motivation for the choice of these variables are described

[6] To reduce the impact of extreme observations, the inflation rate is transformed as $\frac{\pi/100}{1+\pi/100}$.

in De Mendonça and de Guimarães e Souza (2012) and in Chapter 3 of this thesis. Additionally, to control for time fixed effects in IT adoption, we include a time trend.

The data for these variables were collected from the following sources: World Development Indicators, IMF International Financial Statistics, IMF Historical Public Debt Database, Eurostat, national statistics, Ilzetzki et al. (2011) based on Reinhart and Rogoff (2004) for exchange rate regimes, and Chinn and Ito (2008) for the financial openness index.

To make our results from the PSM comparable with the difference-in-differences method, we follow similar procedures. That is, we examine advanced countries, and emerging and developing countries separately. We use for PSM two adoption dates ('loose' and 'strict') and two time periods for each sample: 1985–2011 and 1990–2011 for advanced countries, 1990–2011 and 1996–2011 for emerging and developing countries.

### 6.4.4 Descriptive statistics

The experience of IT and non-IT countries with inflation can be compared by analyzing their time series. Figures 6.1 and 6.2-6.3 present the average inflation rate in advanced countries and emerging and developing ones, respectively. As Figure 6.1 shows, the average inflation rate of advanced IT countries was higher than inflation in non-IT countries in the period 1985–1989, but from 1990 it declined substantially over time. This trend is also observable after IT adoption. However, inflation has also decreased in non-IT countries. It seems that average inflation in both country groups had converged to a lower global mean before most countries adopted IT, suggesting no substantial effect of this monetary strategy on inflation reduction. Additionally, during the Global Financial Crisis in 2008–2010 average inflation rates in both IT and non-IT countries have increased.

Figure 6.2 shows that average inflation in emerging and developing IT countries has been higher than in non-IT countries before IT adoption, but decreased after adoption. In this graph we exclude observations for countries that experienced hyperinflation, i.e. annual inflation rates over 50%, for

Figure 6.1. **Average inflation in advanced IT and non-IT countries, 1985–2011**

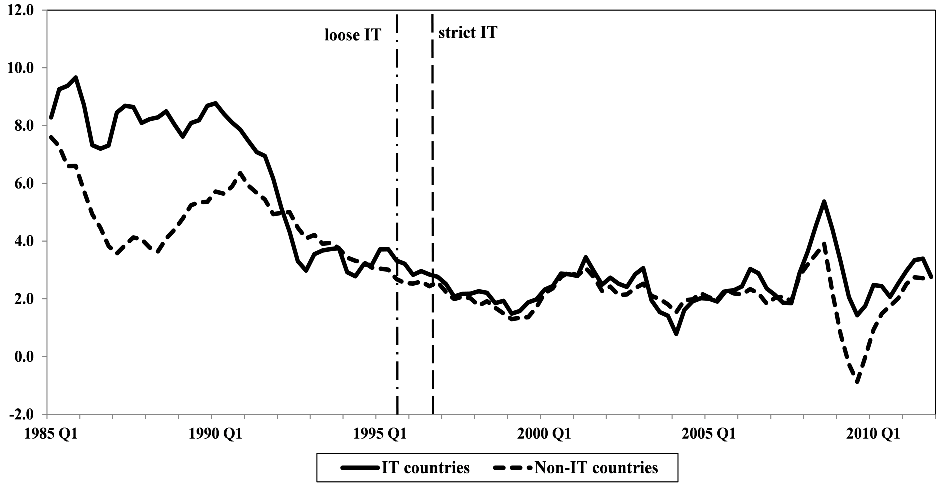
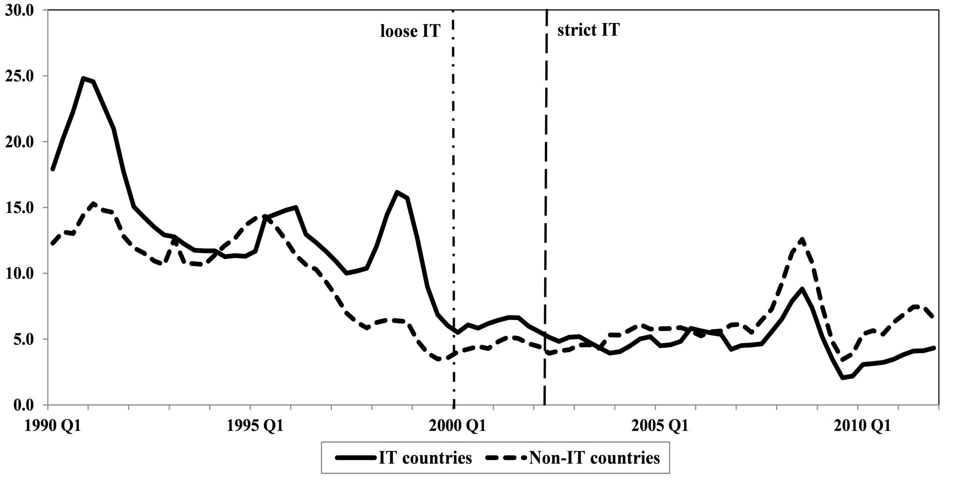
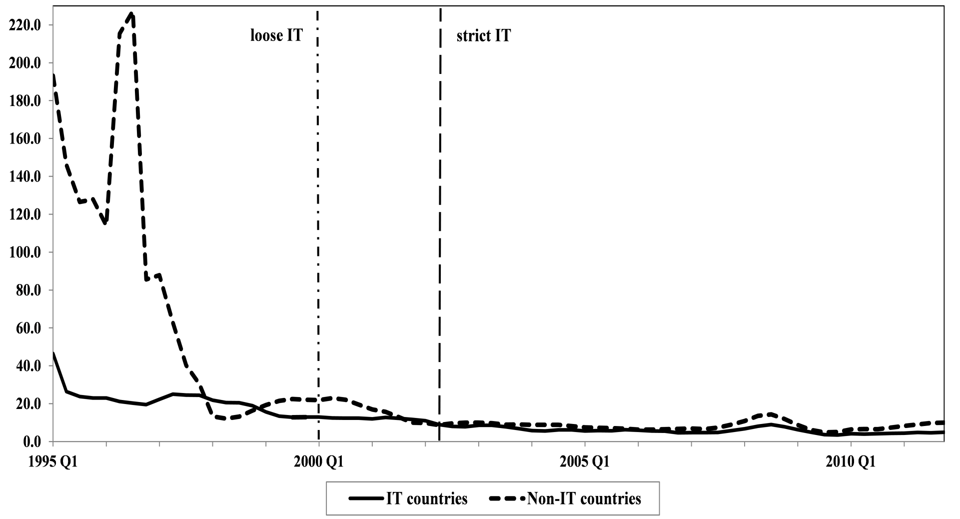



Figure 6.2. **Average inflation in emerging and developing IT and non-IT countries, 1990–2011 (excluding countries with hyperinflation)**



longer than a year. Figure 6.3 plots average inflation for all emerging and developing countries in our sample. Now we observe a more noticeable difference between IT and non-IT countries: the average inflation of emerging and developing IT countries is lower than in non-IT countries throughout the entire time period. The common feature of the graphs is that inflation rates have converged globally, suggesting that regression-to-the-mean is strong.

Figure 6.3. **Average inflation in emerging and developing IT and non-IT countries, 1995–2011 (including countries with hyperinflation)**




*Note:* In this graph we use the time period from 1995. During the years 1990–1994, average inflation in emerging and developing countries was extremely high and in some quarters reached over 1000%. Adding such high values in the graph would make the low values indistinguishable.

Tables C.2-C.3 in the Annex present the descriptive statistics for average inflation and its volatility in IT and non-IT countries, calculated for the pre- and post-adoption periods. Advanced inflation targeters show a larger decline of average inflation than non-inflation targeters; however, they also had higher inflation before IT adoption (see Table C.2). Similar results are found for average inflation volatility in advanced countries. Opposite findings are reported for emerging and developing countries (see Table C.3). Here, average inflation level and its volatility declined more in the group of non-inflation targeters, which are also characterized by higher initial inflation (volatility) than IT countries.

## 6.5 Estimation results

### 6.5.1 Difference-in-differences method

#### Advanced countries

Columns (1)-(4) of Table 6.3 present the estimation results for advanced countries. We estimate Equation 6.1 for two periods (1985–2011 and 1990–2011) and two adoption dates ('loose' and 'strict'). The residuals diagnostics do not suggest the presence of heteroscedasticity in the error terms. This could be explained by the high degree of homogeneity within the group of advanced countries as well as a small number of observations in the analyzed sample (Ball, 2010). Hence, we use OLS standard errors.

Our findings suggest that, regardless of the chosen time period and adoption dates, the coefficient estimate of IT dummy is insignificant. Thus, IT does not have a significant effect on inflation in advanced countries. Moreover, the positive sign of $\beta_2$ implies that advanced inflation targeters experienced a smaller decline in inflation than non-inflation targeters. Apparently, the largest contribution to the inflation decrease can be subscribed to regression-to-the-mean, as the initial inflation is significant with a negative sign. This implies that inflation would have decreased in IT countries even if they had not applied IT. The results are robust to different time periods and adoption dates.

We compare our results to Ball and Sheridan (2004), since their study is the closest to ours in terms of methodology and sample. Our findings differ from Ball and Sheridan (2004) mainly in the sign of the IT dummy. They find that IT has a negative, although insignificant, effect on the inflation reduction. The difference in findings could be due to the choice of the analyzed time period — in our study the period is 10 years longer than in Ball and Sheridan (2004) and includes the years of the recent financial crisis. Additionally, our study includes five more advanced IT countries.

Table 6.3. **Difference-in-differences estimation results for advanced countries**

| | (1) | (2) | (3) | (4) | Ball and Sheridan (2004), p. 258 | |
|---|---|---|---|---|---|---|
| Sample period | 1985–2011 | | 1990–2011 | | 1985–2001 | |
| Adoption dates | Loose | Strict | Loose | Strict | Non-constant[a] | Constant[a] |
| IT dummy | 0.267 | 0.294 | 0.400 | 0.363 | −0.550 | −0.510 |
| | (0.434) | (0.444) | (0.438) | (0.418) | (0.350) | (0.340) |
| Initial inflation | −0.948 *** | −0.961 *** | −0.823 *** | −0.866 *** | −0.780 *** | −0.760 *** |
| | (0.016) | (0.026) | (0.054) | (0.067) | (0.070) | (0.070) |
| Constant | 1.882 *** | 1.879 *** | 1.300 *** | 1.502 *** | 1.120 *** | 1.010 *** |
| | (0.301) | (0.318) | (0.386) | (0.397) | (0.320) | (0.330) |
| Observations | 25 | 25 | 24 | 25 | 20 | 20 |
| $R^2$ | 0.99 | 0.99 | 0.92 | 0.88 | 0.90 | 0.87 |

*Notes:* The table reports coefficient estimates and their standard errors (in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.
[a] Non-constant and constant adoption dates in Ball and Sheridan (2004) are similar to 'loose' and 'strict' adoption dates, respectively, used in this chapter.

To check whether the results are sensitive to sample modifications, we perform two robustness tests. First, we exclude Spain and Finland from the sample, as they abandoned IT in 1999 in order to adopt the euro. Second, instead of dropping both countries completely, we only discard their observations from the first quarter of 1999. Both robustness checks produce qualitatively similar results to those reported in Table 6.3 (results available on request).

This analysis has shown that for advanced countries IT does not have a significant effect on inflation reduction in IT countries, compared to non-inflation targeters.

### Emerging and developing countries

Similar models are estimated for the sample of emerging and developing countries. We use two estimation periods (1990–2011 and 1996–2011) and two adoption dates ('loose' and 'strict').

Since several emerging and developing countries experienced periods of hyperinflation (especially Latin American and transition economies), these observations can influence the results substantially. Two approaches can be used to deal with this issue. The most common approach is to remove the high-inflation countries completely from the estimation. The other method suggested in the literature (Gonçalves and Salles, 2008) is to only remove the observations with exceptionally high inflation in such countries and replace them with the average inflation of more stable periods. Although Gonçalves and Salles (2008) acknowledge some selection problems with this method, they see it as inevitable since their sample decreases so dramatically if they remove all observations for high-inflation countries, that they cannot produce reliable results. Ball (2010) criticizes this method because it is unclear how it affects the estimation results.

We follow the first approach and estimate the models separately for the full sample including high-inflation countries (Table 6.4) and for the sample without these countries (Table 6.5). In the presence of heteroscedasticity, the models are estimated with robust (White-corrected) standard errors.

Table 6.4 presents the estimation results with all 59 emerging and developing countries included. The coefficient of the IT dummy has a negative sign in all the models, suggesting that emerging and developing IT countries experienced a larger decline in inflation compared to non-IT counterparts. The coefficient of $\beta_2$ is also much larger than for advanced countries. Moreover, in the estimations for 'strict' adoption dates the IT dummy is significant, indicating that IT implementation significantly reduces inflation in emerging and developing countries. However, this effect becomes insignificant once we consider 'loose' adoption dates. Regression-to-the-mean is evident here as well, since the initial inflation level has a significant impact on the decline of inflation over time.

Our results are in line with those of Batini and Laxton (2006), Gonçalves and Salles (2008), and Gemayel et al. (2011) who also find a significant impact of IT on inflation decline in emerging and developing countries.

Turning to the estimation results excluding the high-inflation countries[7], Table 6.5 shows that the coefficient of the IT dummy is significant with a negative sign in most models. In addition, the initial inflation level is significant with a negative sign in all estimations. This result suggests that IT indeed

[7] See Table C.1 in the Annex for the countries concerned.

Table 6.4. **Difference-in-differences estimation results for emerging and developing countries, full sample**

| | (1) | (2) | (3) | (4) | Gonçalves and Salles (2008) Table 2, model 3 | Gemayel et al. (2011) Table 2, model 5 |
|---|---|---|---|---|---|---|
| Sample period | 1990–2011 | | 1996–2011 | | 1990–2005 | 1990–2008 |
| Adoption dates | Loose | Strict | Loose | Strict | | |
| IT dummy | −3.085 | −2.612 ** | −1.694 | −2.070 ** | −1.990* | −1.620 * |
| | (2.069) | (1.115) | (1.288) | (0.964) | | (0.980) |
| Initial inflation | −0.994 *** | −0.996 *** | −0.960 *** | −0.976 *** | −0.710*** | −0.780 *** |
| | (0.006) | (0.004) | (0.002) | (0.002) | | (0.070) |
| Constant | 8.580 *** | 7.594 *** | 7.392 *** | 7.197 *** | 2.230* | 4.640 *** |
| | (1.104) | (0.819) | (0.995) | (0.744) | | (1.010) |
| Observations | 59 | 59 | 56 | 59 | 36 | 39 |
| $R^2$ | 0.99 | 0.99 | 0.99 | 0.99 | 0.86 | 0.78 |

*Notes:* The table reports coefficient estimates and their robust (White-corrected) standard errors (in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Table 6.5. **Difference-in-differences estimation results for emerging and developing countries, without countries with hyperinflation**

| | (1) | (2) | (3) | (4) | Gemayel et al. (2011) Table 2, models 1,3 | |
|---|---|---|---|---|---|---|
| Sample period | 1990–2011 | | 1996–2011 | | 1990–2008 | 1996–2008 |
| Adoption dates | Loose | Strict | Loose | Strict | | |
| IT dummy | −1.340 | −2.340 ** | −1.442 * | −2.775 *** | −1.960 * | −2.210 * |
| | (0.950) | (0.998) | (0.856) | (0.786) | (1.050) | (0.870) |
| Initial inflation | −0.668 *** | −0.689 *** | −0.699 *** | −0.643 *** | −0.730 *** | −0.790 *** |
| | (0.076) | (0.107) | (0.079) | (0.090) | (0.090) | (0.080) |
| Constant | 2.232 *** | 3.179 *** | 3.617 *** | 4.104 *** | 3.90 *** | 5.45 *** |
| | (0.782) | (1.012) | (0.804) | (0.869) | (1.110) | (0.930) |
| Observations | 32 | 32 | 45 | 48 | 26 | 38 |
| $R^2$ | 0.81 | 0.75 | 0.74 | 0.68 | 0.76 | 0.75 |

*Notes:* The table reports coefficient estimates and their robust (White-corrected) standard errors (in parentheses). ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

contributed to inflation reduction in emerging and developing countries. The IT dummy is only insignificant for 'loose' adoption dates in the period 1990–2011, indicating that results are somewhat sensitive to the choice of adoption dates.

Similarly to the analysis for advanced countries, we take into account that one country in the sample of emerging and developing economies, Slovakia, abandoned IT in 2009 in order to adopt the euro. We perform sensitivity tests by excluding Slovakia from the sample as well as by dropping its observations from 2009. These modifications do not influence our main results (available on request).

To conclude, we find evidence that IT implementation significantly reduces inflation in emerging and developing countries. Once we exclude countries with hyperinflation, the effects of IT on inflation performance in emerging and developing countries become more pronounced.

### 6.5.2 Propensity Score Matching method

#### Advanced countries

We conduct the analysis for two adoption dates ('loose' and 'strict') and two periods (1985–2011 and 1990–2011). Table 6.8 presents the estimation results of the propensity scores for the sample of advanced countries. We exclude broad money growth from the set of covariates, as it is insignificant in all models. The chosen model specifications satisfy the Balancing Hypothesis.

We find that advanced countries with lower GDP per capita, more flexible exchange rate regimes, lower financial development, and higher trade openness are more likely to choose IT. The coefficient of the time trend is significant with a positive sign, indicating that as time passes, the probability of a country to adopt IT increases. Other variables are not significant. Our findings differ from Lin and Ye (2007) who report negative and significant coefficient estimates of lagged inflation and trade openness. Such a difference in results could be due to the fact that the authors examine advanced countries during 1985–1999, while our analyzed period is extended until

Table 6.6. **Estimates of the treatment effect on inflation, advanced countries**

| | Matching methods | | | | | | |
|---|---|---|---|---|---|---|---|
| Adoption dates | Nearest-neighbor | Radius, r = 0.005 | Radius, r = 0.02 | Radius, r = 0.04 | Kernel, Gaussian | Kernel, Epanechn. | Stratification |
| | | | 1985–2011 | | | | |
| Loose | −0.093 | −0.615 | −0.837 ** | −0.801 ** | −0.030 | −0.126 | −0.034 |
| | (0.604) | (0.477) | (0.348) | (0.325) | (0.420) | (0.349) | (0.308) |
| Strict | −1.216 | −0.704 * | −0.518 * | −0.580 ** | −0.527 | −0.742 | −0.370 |
| | (0.830) | (0.420) | (0.288) | (0.243) | (0.631) | (0.688) | (0.588) |
| | | | 1990–2011 | | | | |
| Loose | −0.114 | 0.105 | −0.069 | −0.071 | −0.090 | −0.293 | −0.091 |
| | (0.619) | (0.489) | (0.340) | (0.290) | (0.408) | (0.358) | (0.360) |
| Strict | −0.521 | −0.346 | −0.399 | −0.353 | −0.489 | −0.616 | −0.299 |
| | (0.874) | (0.396) | (0.276) | (0.246) | (0.670) | (0.741) | (0.568) |

*Notes:* The 0.06 fixed bandwidth is used for Epanechnikov and Gaussian kernels. Bootstrapped standard errors (based on 1000 replications of the data) are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

2011. Our conclusions differ also from De Mendonça and de Guimarães e Souza (2012) for some variables, possibly because they estimate propensity scores for all countries together.

Table 6.6 reports the estimated ATTs on the level of inflation. Our findings suggest that in most cases, regardless of the time period and adoption dates, the ATTs are insignificant. This holds in all estimations for nearest-neighbor, kernel, and stratification matching. Interestingly, for the period 1985–2011 the effect of IT on inflation is negative and significant for all three radiuses. However, these effects become insignificant once wider radiuses are used.[8] Our findings for the ATTs are comparable to the results of Lin and Ye (2007) and De Mendonça and de Guimarães e Souza (2012).

We conduct sensitivity tests by excluding Spain and Finland from the sample as well as by discarding their observations from 1999. Both modifications produce similar results to the main ones.

[8] As a robustness check, we applied radius matching with r = 0.05; 0.075; 0.1. All the estimated ATTs were insignificant. These results are available on request.

### Emerging and developing countries

A similar PSM estimation procedure is applied for emerging and developing countries. We use again two periods (1990–2011 and 1996–2011) and two adoption dates ('loose' and 'strict'). Additionally, to take into account the hyperinflation episodes in some countries, we conduct the PSM separately for the sample with high-inflation countries and without these countries. Table 6.8 reports the logit estimates of the propensity scores. We exclude financial development, since it was insignificant; also, the model specification without this variable satisfies the Balancing Hypothesis.

Our findings from the propensity score estimations suggest that emerging and developing countries with lower past inflation, higher GDP per capita, more flexible exchange rate regimes, lower money growth, lower government debt, lower trade openness, and higher financial openness are more likely to adopt IT. Additionally, the time trend is significant with a positive sign. The results are robust to the exclusion of high-inflation countries. These findings are consistent with the results of Lin and Ye (2009) and De Mendonça and de Guimarães e Souza (2012).

Table 6.7 presents the estimated ATTs on the level of inflation. For the full sample, the ATTs are all found to be statistically significant and negative, for all adoption dates and time periods. For the sample without high-inflation countries the ATTs are also significant with a negative sign in most of applied matching methods. However, for 'strict' dates in the period 1990–2011 only the ATT from stratification matching is significant.

We perform a sensitivity analysis by excluding Slovakia from the sample as well as by dropping its observations from 2009. These modifications do not change the main results.

Our estimated results of the ATTs for emerging and developing countries are in line with the findings of Lin and Ye (2009) and De Mendonça and de Guimarães e Souza (2012). We find strong evidence that IT significantly reduces inflation in emerging and developing countries. These outcomes remain robust to different adoption dates, time periods analyzed as well as sample modifications.

Table 6.7. **Estimates of the treatment effect on inflation, emerging and developing countries**

| Matching methods | | | | | | | |
|---|---|---|---|---|---|---|---|
| Adoption dates | Nearest-neighbor | Radius, r = 0.005 | Radius, r = 0.02 | Radius, r = 0.04 | Kernel, Gaussian | Kernel, Epanechn. | Stratification |
| **Full sample** | | | | | | | |
| 1990–2011 | | | | | | | |
| Loose | −3.618 ** | −3.676 *** | −4.165 *** | −4.322 *** | −5.118 *** | −5.251 *** | −5.572 *** |
| | (1.838) | (1.071) | (0.792) | (0.675) | (1.013) | (1.208) | (1.287) |
| Strict | −3.298 ** | −2.724 *** | −2.699 *** | −2.761 *** | −3.360 *** | −2.986 *** | −2.972 *** |
| | (1.568) | (0.803) | (0.527) | (0.446) | (1.010) | (1.155) | (0.806) |
| 1996–2011 | | | | | | | |
| Loose | −7.954 *** | −3.056 *** | −3.113 *** | −2.884 *** | −5.675 *** | −5.847 *** | −5.475 *** |
| | (2.284) | (0.980) | (0.682) | (0.602) | (1.441) | (1.721) | (1.694) |
| Strict | −3.475 * | −2.566 *** | −2.733 *** | −2.707 *** | −3.691 *** | −3.209 ** | −3.164 *** |
| | (1.832) | (0.621) | (0.532) | (0.472) | (1.206) | (1.322) | (0.926) |
| **Without countries with hyperinflation** | | | | | | | |
| 1990–2011 | | | | | | | |
| Loose | −10.728 ** | −0.556 | −1.650 * | −1.755 ** | −6.233 ** | −7.712 ** | −9.813 ** |
| | (4.762) | (1.332) | (0.978) | (0.884) | (2.916) | (3.299) | (4.539) |
| Strict | −1.712 | −1.249 | −1.115 | −1.054 | −1.936 | −0.402 | −1.629 *** |
| | (1.864) | (1.359) | (0.843) | (0.713) | (1.386) | (1.037) | (0.622) |
| 1996–2011 | | | | | | | |
| Loose | −2.303 | −1.653 ** | −1.907 *** | −1.957 *** | −2.804 ** | −2.436 * | −2.685 *** |
| | (2.036) | (0.806) | (0.525) | (0.499) | (1.217) | (1.362) | (0.753) |
| Strict | −4.720 *** | −2.639 *** | −2.539 *** | −2.382 *** | −2.590 *** | −2.863 *** | −2.706 *** |
| | (1.239) | (0.817) | (0.546) | (0.498) | (0.839) | (0.868) | (0.790) |

*Notes:* The 0.06 fixed bandwidth is used for Epanechnikov and Gaussian kernels. Bootstrapped standard errors (based on 1000 replications of the data) are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% significance level, respectively.

Thus, both estimation techniques — difference-in-differences and PSM — yield similar results in terms of the effect of IT on inflation. The general observation from the empirical analysis is that while IT has no significant influence on inflation reduction in advanced countries, it contributes substantially to decreasing inflation in emerging and developing economies.

## 6.6 Conclusion

This chapter conducts a comprehensive robustness analysis of IT effects on inflation. We examine to what extent the outcomes are sensitive to the choice of country samples, time periods, and IT adoption dates. In doing so, we use as large a sample as possible and carefully select countries included in

Table 6.8. **Propensity score estimations: logit model**

| | Advanced countries | | | | Emerging and developing countries | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Full sample | | | | Without countries with hyperinflation | | | |
| Sample period | 1985–2011 | | 1990–2011 | | 1990–2011 | | 1996–2011 | | 1990–2011 | | 1996–2011 | |
| Adoption dates | Loose | Strict | Loose | Strict | Loose | Strict | Loose | Strict | Loose | Strict | Loose | Strict |
| Inflation$_{t-1}$ | −2.110 | −10.656 | 4.288 | −6.632 | −8.603 *** | −18.927 *** | −11.934 *** | −18.575 *** | −4.899 | −24.529 *** | −8.694 *** | −11.706 *** |
| | (5.668) | (7.901) | (7.212) | (9.059) | (1.771) | (3.080) | (2.269) | (3.061) | (3.304) | (6.814) | (2.581) | (3.262) |
| GDP per capita (ln) | −2.087 *** | −1.825 *** | −2.332 *** | −1.872 *** | 0.568 *** | 0.080 | 0.436 *** | 0.095 | 1.622 *** | 1.060 *** | 0.456 ** | 0.170 |
| | (0.469) | (0.519) | (0.513) | (0.530) | (0.145) | (0.184) | (0.159) | (0.184) | (0.283) | (0.353) | (0.165) | (0.186) |
| Exchange rate regime | 0.568 *** | 0.542 *** | 0.576 *** | 0.535 *** | 0.474 *** | 0.670 *** | 0.573 *** | 0.673 *** | 0.595 *** | 0.859 *** | 0.626 *** | 0.706 *** |
| | (0.052) | (0.053) | (0.054) | (0.053) | (0.044) | (0.065) | (0.052) | (0.065) | (0.064) | (0.098) | (0.060) | (0.071) |
| Broad money growth | | | | | −0.030 *** | −0.056 *** | −0.037 *** | −0.054 *** | −0.007 | −0.078 *** | −0.027 *** | −0.046 *** |
| | | | | | (0.008) | (0.011) | (0.009) | (0.011) | (0.010) | (0.024) | (0.010) | (0.013) |
| Financial development | −2.012 *** | −1.910 *** | −1.817 *** | −1.794 *** | | | | | | | | |
| | (0.364) | (0.388) | (0.374) | (0.391) | | | | | | | | |
| Government debt | 0.003 | −0.003 | 0.002 | −0.003 | −0.018 *** | −0.017 *** | −0.018 *** | −0.017 *** | −0.010 | −0.013 | −0.021 *** | −0.018 *** |
| | (0.004) | (0.005) | (0.004) | (0.005) | (0.005) | (0.006) | (0.005) | (0.006) | (0.008) | (0.010) | (0.005) | (0.006) |
| Trade openness | 0.011 *** | 0.010 ** | 0.013 *** | 0.010 ** | −0.013 *** | −0.010 *** | −0.012 *** | −0.010 *** | −0.022 *** | −0.025 *** | −0.012 *** | −0.009 *** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.002) | (0.002) | (0.002) | (0.002) | (0.004) | (0.005) | (0.003) | (0.002) |
| Financial openness | 0.040 | 0.241 | 0.168 | 0.282 | 0.139 * | 0.259 *** | 0.187 ** | 0.253 *** | 0.318 *** | 0.866 *** | 0.139 | 0.185 * |
| | (0.162) | (0.197) | (0.195) | (0.215) | (0.078) | (0.094) | (0.083) | (0.093) | (0.119) | (0.171) | (0.087) | (0.097) |
| Time trend | 0.316 *** | 0.334 *** | 0.268 *** | 0.305 *** | 0.081 *** | 0.234 *** | 0.087 *** | 0.211 *** | 0.181 *** | 0.357 *** | 0.108 *** | 0.227 *** |
| | (0.035) | (0.037) | (0.036) | (0.039) | (0.021) | (0.031) | (0.027) | (0.033) | (0.034) | (0.054) | (0.029) | (0.035) |
| Observations | 619 | 619 | 523 | 523 | 1109 | 1109 | 908 | 908 | 630 | 630 | 750 | 750 |
| Common support | [0.002, 0.998] | [0.018, 0.997] | [0.005, 0.997] | [0.024, 0.996] | [0.010, 0.890] | [0.006, 0.962] | [0.004, 0.922] | [0.006, 0.959] | [0.024, 0.991] | [0.013, 0.999] | [0.017, 0.945] | [0.015, 0.969] |
| Pseudo $R^2$ | 0.48 | 0.51 | 0.46 | 0.48 | 0.38 | 0.51 | 0.41 | 0.47 | 0.50 | 0.65 | 0.40 | 0.45 |

*Notes:* This table reports coefficient estimates and their standard errors (in parentheses). ***, **, * denote significance at the 1%, 5%, and 10% significance level, respectively. Constant terms are included but not reported. The balancing property is satisfied in all models. Common support restriction implies that the test of the balancing property is performed only on observations whose propensity scores belong to the intersection of the supports of propensity score of treated and control units (Becker and Ichino, 2002).

the control group. Moreover, we apply two methodological approaches — the difference-in-differences technique and the PSM method — to check the robustness of our conclusions to the method used. Both approaches produce qualitatively similar results.

We find that there is a large difference between country samples. IT has no impact on inflation in advanced countries, while it significantly reduces inflation in emerging and developing countries. A possible explanation for this difference is that emerging and developing countries lacked credibility in monetary policy conduct. The decision to adopt IT in such economies signaled a strong commitment of monetary authorities to achieving price stability. As a result, credibility of central banks increased, which helped to anchor inflation expectations.

Another reason why the results for emerging and developing countries may differ is that advanced countries represent a more homogenous group in terms of their characteristics and performance. In contrast, emerging and developing countries are a very heterogeneous group with more diverse initial conditions. For instance, some countries experienced hyperinflation. Dropping these countries makes the negative impact of IT on inflation in emerging and developing countries more pronounced.

*Chapter 7*

# Conclusion

## 7.1 Main findings

This empirical thesis focuses on two monetary policy strategies, namely monetary targeting and inflation targeting. In particular, the thesis addresses the following four research questions:

1. Do financial system changes affect the decision to abandon monetary targeting?
2. Which determinants drive inflation targeting adoption?
3. How do spatial interactions between countries influence the decision to adopt inflation targeting?
4. Does inflation targeting influence inflation and does this impact vary across countries?

Chapter 2 answers the first research question and examines how financial system reforms and characteristics affect the likelihood of countries to abandon monetary targeting. Additionally, we include macroeconomic, fiscal, external, and institutional control variables associated with countries' decisions to leave this monetary strategy. Our findings suggest that countries with liberalized, deregulated, developed, and dollarized financial systems are more likely to abandon monetary targeting. Moreover, the exchange rate regime in place affects the probability to give up monetary targeting conditional on the level of capital mobility. In line with the *policy trilemma* hypothesis, our results show that countries with limited capital mobility can use money growth targets and keep fixed exchange rates at the same time. However, when capital mobility is high, a fixed exchange rate regime is incompatible with monetary targeting. Additionally, we find that more developed countries with lower inflation and larger fiscal deficits are more likely to abandon monetary targeting. Importantly, the outcomes for emerging and developing countries differ from those for advanced economies. In particular, financial dollarization increases the probability to leave monetary targeting in advanced countries, whereas financial development is significant in emerging and developing countries. Financial liberalization has a significant impact in advanced as well as emerging and developing countries.

Chapter 3 addresses the second research question by investigating which economic, fiscal, external, financial, and institutional factors affect the likelihood to adopt inflation targeting. The novelty of our approach is in excluding the post-adoption period from the empirical analysis. The results suggest that countries with low inflation, high output and exchange rate volatility, a flexible exchange rate regime, and lower government debt are more likely to adopt inflation targeting. In addition, countries with less developed financial markets and a market-based financial system are more likely to adopt this strategy. The outcomes differ slightly between soft and full-fledged inflation targeting adoption; inflation is found less important for adopting soft than for full-fledged inflation targeting. As a robustness check, we distinguish two types of inflation targeting based on the number of nominal targets — inflation targeting with multiple targets and inflation targeting with a single, inflation target. We find that different explanatory variables affect the probability to adopt different types of inflation targeting. Additionally, the probability to switch from inflation targeting with multiple targets to inflation targeting with a single target is affected by lower inflation and output growth, better fiscal discipline and flexible exchange rate regimes. Finally, our sensitivity analysis shows that the factors leading to inflation targeting adoption differ between OECD and non-OECD countries. This result can be explained by the fact that there are substantial differences between these country groups in terms of their macroeconomic characteristics, credibility of their central banks, and monetary policy objectives.

Chapter 4 provides further evidence on the factors of inflation targeting adoption. We test whether country characteristics influence the decision to apply inflation targeting differently before and after its adoption. We use a structural break analysis and include a smooth transition function to distinguish between the pre- and post-adoption periods. The findings suggest that there is a structural change in economic and institutional characteristics occurring during and after adoption. The factors leading to inflation targeting adoption differ significantly between the periods before and after adoption. Inflation has the most prominent role, as its effect on the probability to adopt inflation targeting is largely overestimated in the model that includes the post-adoption period compared to the one without this period. Thus, including the post-adoption period in the empirical analysis of inflation targeting adoption produces biased results. To eliminate this bias it is necessary to discard observations after adoption, as was done in Chapters 3 and 5.

Chapter 5 adds a spatial econometric aspect into the analysis of inflation targeting adoption. We construct a spatial probit model with two spatially lagged variables, one for countries that did not adopt inflation targeting yet at the start of the period and one for countries that already adopted this strategy. Three spatial weights matrix specifications are used: ten-nearest neighbors, common language, and common legal origins. We find that the estimation results are sensitive to the choice of the spatial weights matrix. For the common language weights matrix, the interaction effects with countries that adopt inflation targeting in the current period are insignificant, while the countries that already adopted it have a significant negative impact on others to adopt. A possible explanation for this negative impact is that over time the probability to adopt inflation targeting decreases as the number of neighboring countries that did not adopt yet diminishes. For the spatial weight matrix based on common legal origins, we find that countries which adopt inflation targeting in the current period significantly increase the probability of others to adopt this strategy in the same period. For the ten-nearest neighbors' spatial weights matrix, both spatial terms are insignificant. Additionally, we find evidence for spatial spillover effects of countries' characteristics on inflation targeting adoption.

Chapter 6 addresses the final research question in an extensive analysis of the effects of inflation targeting on inflation. We examine the sample of advanced and emerging and developing countries separately, using two different adoption dates ('loose' and 'strict') and two time periods for each sample. To explore whether outcomes depend on the choice of methodology, we apply two estimation techniques — difference-in-differences and propensity score matching. The estimation results differ substantially between country samples. Inflation targeting has no significant effect on inflation in advanced countries, while it significantly decreases inflation in emerging and developing countries. Moreover, excluding high-inflation countries from the latter sample enhances the negative impact of inflation targeting. Additionally, the outcomes are sensitive to the choice of adoption dates. Finally, both methodological approaches arrive at similar conclusions.

## 7.2 Policy implications

The findings of this thesis have several policy implications. First, the analyses of monetary targeting abandonment and inflation targeting adoption have shown that financial system characteristics play an important role in the choice of a monetary policy strategy. In the aftermath of the Global Financial Crisis 2008–2010, many central banks started modifying their monetary policy frameworks to combine the objective of price stability with the goal of financial stability. Given that at present having low and stable inflation is less of a problem for advanced countries, more emphasis is put on adjusting monetary policy strategies to deal with financial system imbalances. In this light, financial system characteristics matter for the monetary strategy choice.

As for monetary targeting, our findings suggest that financial system changes contribute to the abandonment of monetary targeting. These results are relevant mainly for emerging and developing countries that are still using this strategy. Such countries are going through the financial evolution processes that include deregulation, liberalization, and development. In these circumstances, they may soon experience increasing instability of money demand that makes monetary targeting ineffective in reaching its objectives. Thus, it is recommended for emerging and developing countries, which apply monetary targeting, to identify and monitor the changes in their financial systems that may lead to countries' decision to leave monetary targeting.

Second, the analysis of inflation targeting adoption suggests that the factors leading to adoption differ between OECD and non-OECD countries. In the pre-adoption period, non-OECD countries have higher inflation and financial instability, worse fiscal discipline, and lower central bank independence than OECD countries. Therefore, emerging and developing (non-OECD) countries, which consider implementing inflation targeting in the future, are recommended to prepare well for adoption through improving their macroeconomic performance, financial markets, fiscal discipline, and institutional framework. Additionally, given that many emerging and developing countries suffer from high inflation before adoption, they are advised first to adopt a soft version of inflation targeting (with multiple targets) that involves less commitment to the inflation target, but at the same time signals to the public the long-term goal to achieve price stability. Once this strategy succeeds in bringing down inflation to sustainable levels and increasing credibility of central banks, it is possible to switch to full-fledged inflation targeting with a strong commitment to the single, inflation target.

Finally, the institutional framework of a central bank and its communication strategy matter for the conduct of monetary policy and its effectiveness. Establishing a strong commitment to a nominal target (money growth or inflation) is crucial for achieving price stability and enhancing credibility of monetary authorities. Central bank independence matters, too. Although we did not find that central bank independence drives the adoption of inflation targeting, it is the case that institutions improve only after adoption. Apparently, some countries consider adopting inflation targeting as a starting point of economic and institutional reforms (Hammond, 2012), which will lead to better macroeconomic performance and monetary policy conduct. A very important institutional aspect is also transparency of a central bank in communicating its strategy to the public. Opaque communication of monetary policy-making reduces the central bank's credibility and makes it difficult to achieve its objectives. To conclude, central banks are recommended to improve their institutional framework and communication for effective implementation of any monetary policy strategy.

## 7.3 Directions for future research

There are several possible directions for future research in the area of monetary policy strategies. Chapter 5 proposed a spatial probit model with two spatially lagged variables. However, this chapter focused mainly on the methodological innovation, which was supplemented with an illustration for inflation targeting adoption. In future work, it would be worth to extend this study by conducting a full-fledged analysis of spatial interactions in inflation targeting adoption. The robustness of results could be tested by using different adoption dates, country samples, a larger set of explanatory variables as well as various spatial weights matrices that control for economic, financial, political, and other dimensions of proximity between countries.

In Chapter 6 we mention that one shortcoming of the literature on inflation targeting adoption and performance is that inflation targeting choice is being treated as binary. That is, the existing studies do not consider that there can be more than one type of inflation targeting. Given that the framework of inflation targeting regimes differs from country to country, future research could concentrate on constructing a comprehensive inflation targeting index that would take into account such criteria as the number of nominal targets used in monetary strategy, the time horizon of the inflation target, central bank's objectives, or transparency in communication of monetary strategy. Having such a multinomial index could bring new insights into the analysis of inflation targeting adoption and the impact of different inflation targeting regimes on macroeconomic performance.

Next, the study of monetary policy strategies could be further extended by examining the timing of inflation targeting (and other strategies) adoption and the impact of this adoption on monetary policy conduct. For this purpose, regime-switching models could be used. Petreski (2011) and Creel and Hubert (2013) apply Markov-switching VAR models to analyze whether inflation targeting adoption constitutes the switch in monetary policy conduct for, respectively, nine emerging and eight advanced countries. However, Markov switching models treat the change in a regime as a rapid switch, whereas the transition to a different monetary strategy is rather a gradual process, which needs time for adjusting economic and institutional fundamentals to the new framework. Thus, it would be worth to examine the changes of monetary strategies by applying a methodological approach that allows for slow transition, namely smooth transition autoregressive models.

In several chapters we emphasize inflation as a crucial factor driving inflation targeting adoption and a major focus of this strategy. However, given that many advanced countries have already achieved low inflation, they might choose to apply inflation targeting not to control the level of inflation, but rather to decrease inflation volatility. Thus, it would be interesting to incorporate inflation volatility into the analysis of adoption and performance of inflation targeting (and other monetary strategies), in future research.

This thesis investigated different monetary policy strategies separately. In future research, it would be interesting to analyze all monetary policy strategies simultaneously, using e.g. multinomial choice models.

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# Annex

Table A.1. **Variables and data sources**

| Variable | Description | Expect. sign | Data sources |
|---|---|---|---|
| Financial liberalization | Chinn-Ito index of capital account openness. The index takes values from -1.86 to 2.46. | $+$ | Chinn and Ito (2008) |
| Financial deregulation | Financial deregulation index includes 5 dimensions. On each dimension the scale is $0-3$ ($0=$ full repression, $3=$ full liberalization). The index takes values from 0 to 15. | $+$ | Abiad et al. (2008) |
| Financial development | Domestic credit provided by the banking sector /GDP | $+$ | WDI & GDF World Bank |
| Financial dollarization | Reserves' dollarization: Foreign currency reserves/total reserves. Deposit dollarization: Foreign currency deposits/total bank deposits | $+$ | IFS IMF, Levy-Yeyati (2006), national and central banks' statistics |
| Economic development | GDP per capita (ln), in 2000 USD | $+$ | WDI & GDF World Bank |
| Inflation | Measured as $\frac{\pi/100}{1+\pi/100}$, where $\pi$ denotes the annual CPI inflation rate | $-$ | WEO & IFS IMF |
| Exchange rate regime | Indicator, from 1 (hard peg) to 14 (freely falling). In several cases takes the value 15 (dual market). | $+/-$ | Reinhart and Rogoff (2004), Ilzetzki et al. (2011) |
| Money growth volatility | 3-year rolling standard deviation of annual broad money growth rates (M3 or M2, depending on country data) | $+$ | WDI & GDF World Bank, Datastream |
| Trade openness | Sum of export and import of goods and services as percentage of GDP | $+$ | WDI & GDF World Bank, IFS IMF, national statistics |
| Fiscal balance | General government fiscal balance as percentage of GDP | $-$ | WEO & IFS IMF, Datastream, EBRD reports, World Bank Development reports |
| Central bank independence | Actual central bank independence index (ACBI) $=$ legal index$\times$ rule of law | $-$ | Cukierman et al. (2002), Arnone et al. (2007), ICRG database, central banks' laws |
| Nominal interest rate | Discount rate at which a central bank lends money to banks | $-$ | Datastream |

Table A.2. **Correlation matrix (full sample)**

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Financial liberalization | 1.00 | | | | | | | | | | |
| 2 | Financial deregulation | **0.48** | 1.00 | | | | | | | | | |
| 3 | Financial development | **0.52** | **0.21** | 1.00 | | | | | | | | |
| 4 | Financial dollarization | **-0.30** | 0.00 | **-0.30** | 1.00 | | | | | | | |
| 5 | GDP per capita (ln) | **0.62** | **0.27** | **0.73** | **-0.54** | 1.00 | | | | | | |
| 6 | Inflation | **-0.36** | **-0.25** | **-0.37** | 0.06 | **-0.32** | 1.00 | | | | | |
| 7 | Exchange rate regime | **0.15** | **0.14** | **0.17** | **-0.12** | **0.13** | **0.19** | 1.00 | | | | |
| 8 | Money growth volatility | **-0.15** | -0.01 | -0.26 | **0.11** | **-0.25** | **0.51** | **0.16** | 1.00 | | | |
| 9 | Trade openness | **-0.24** | **0.23** | **-0.36** | **0.40** | **-0.34** | **0.17** | **-0.11** | **0.24** | 1.00 | | |
| 10 | Fiscal balance | **0.20** | **0.39** | **0.09** | **0.08** | **0.16** | **-0.25** | -0.07 | **-0.15** | **0.11** | 1.00 | |
| 11 | Central bank independence | **0.64** | **0.46** | **0.38** | **-0.25** | **0.49** | **-0.33** | 0.01 | -0.08 | 0.02 | **0.18** | 1.00 |

*Note:* Numbers in bold indicate correlation coefficients that are significant at the 5 % significance level.

Table A.3. **Correlation matrix (MT-'leavers')**

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Financial liberalization | 1.00 | | | | | | | | | | |
| 2 | Financial deregulation | **0.55** | 1.00 | | | | | | | | | |
| 3 | Financial development | **0.58** | **0.34** | 1.00 | | | | | | | | |
| 4 | Financial dollarization | **-0.16** | 0.06 | **-0.11** | 1.00 | | | | | | | |
| 5 | GDP per capita (ln) | **0.66** | **0.36** | **0.63** | **-0.35** | 1.00 | | | | | | |
| 6 | Inflation | **-0.45** | **-0.30** | **-0.41** | 0.05 | **-0.40** | 1.00 | | | | | |
| 7 | Exchange rate regime | **0.13** | 0.07 | **0.24** | -0.07 | 0.07 | **0.17** | 1.00 | | | | |
| 8 | Money growth volatility | **-0.19** | -0.05 | -0.27 | **0.15** | **-0.32** | **0.59** | **0.15** | 1.00 | | | |
| 9 | Trade openness | **-0.29** | **0.24** | **-0.39** | **0.41** | **-0.42** | **0.21** | -0.10 | **0.27** | 1.00 | | |
| 10 | Fiscal balance | **0.26** | **0.41** | 0.10 | **0.13** | **0.21** | **-0.26** | -0.07 | **-0.19** | **0.22** | 1.00 | |
| 11 | Central bank independence | **0.70** | **0.51** | **0.33** | **-0.20** | **0.49** | **-0.32** | 0.02 | -0.10 | -0.02 | **0.16** | 1.00 |

*Note:* Numbers in bold indicate correlation coefficients that are significant at the 5 % significance level.

Table B.1. **Variables and data sources**

| Analyzed variable | Description | Expect. sign | Data sources |
|---|---|---|---|
| Inflation | Measured as $\frac{\pi/100}{1+\pi/100}$, where $\pi$ denotes the CPI inflation rate | $-$ | IFS IMF, Datastream |
| Output growth | Annual percentage GDP growth rate | $-$ | WDI & GDF World Bank, IFS IMF |
| Output volatility | Annual standard deviation of monthly Industrial Production growth rates | $+$ | IFS IMF, Datastream |
| Flexible exchange rate regime | Dummy, 1 - floating exchange rate regime, 0 - fixed exchange rate regime | $+$ | Levy-Yeyati and Sturzenegger (2005) |
| Exchange rate volatility | Annual standard deviation of monthly percentage changes in the REER (for Estonia, Guatemala, Latvia, Lithuania, and Sudan - in market exchange rates) | $+$ | IFS IMF, Datastream |
| Fiscal balance | Fiscal balance as percentage of GDP | $+$ | WDI & GDF World Bank, IFS IMF, Datastream |
| Government debt | Central government debt as percentage of GDP | $-$ | Datastream, Jaimovich and Panizza (2010) |
| Trade openness | Sum of export and import as percentage of GDP | $+$ | WDI & GDF World Bank, IFS IMF |
| External exposure | External debt as percentage of GDP | $-$ | WDI & GDF World Bank, IFS IMF |
| Financial instability | Financial crisis dummy, 1 - a financial crisis occurred in a given year, 0 - otherwise | $-$ | Honahan and Laeven (2005), Laeven and Valencia (2008) |
| Financial development | Private credit by deposit money banks and other financial institutions/GDP | $+$ | Financial Structure Dataset, World Bank (April 2010) |
| Market-based financial structure | Dummy, 1 - market-based financial system, 0 - bank-based financial system | $+$ | Calculations based on Financial Structure Dataset, World Bank |
| Central bank instrument independence | Legal index: 1 - central bank is instrument independent, 0 - otherwise. Actual index = legal index$\times$ rule of law | $+$ | Cukierman et al. (1992), Cukierman et al. (2002); Arnone et al. (2007), central banks' laws, ICRG database |
| Financial openness | Chinn-Ito index of capital account openness (KAOPEN) | $+$ | Chinn and Ito (2008) |
| Economic development | Real GDP per capita (ln), in 2000 USD | $+$ | WDI & GDF World Bank |

Table B.2. **Correlation matrix of explanatory variables**

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Inflation | 1.00 | | | | | | | | | | | | |
| 2 | Output growth | -0.04 | 1.00 | | | | | | | | | | | |
| 3 | Output volatility | -0.13 | -0.18 | 1.00 | | | | | | | | | | |
| 4 | Flexible exchange rate regime | 0.12 | 0.04 | -0.24 | 1.00 | | | | | | | | | |
| 5 | Exchange rate volatility | 0.34 | -0.29 | -0.12 | 0.15 | 1.00 | | | | | | | | |
| 6 | Fiscal balance | -0.18 | 0.27 | -0.13 | -0.19 | -0.13 | 1.00 | | | | | | | |
| 7 | Government debt | -0.19 | 0.11 | 0.36 | -0.03 | -0.04 | -0.13 | 1.00 | | | | | | |
| 8 | Trade openness | -0.20 | 0.27 | -0.01 | -0.31 | -0.11 | 0.58 | 0.11 | 1.00 | | | | | |
| 9 | External debt | -0.14 | -0.09 | 0.01 | -0.24 | -0.11 | 0.06 | -0.03 | 0.12 | 1.00 | | | | |
| 10 | Financial crisis | 0.12 | -0.26 | -0.05 | 0.13 | 0.39 | -0.22 | 0.04 | -0.13 | -0.09 | 1.00 | | | |
| 11 | Market-based financial structure | 0.12 | 0.08 | -0.35 | 0.16 | 0.07 | 0.04 | 0.01 | 0.11 | -0.07 | 0.13 | 1.00 | | |
| 12 | Financial development | -0.41 | -0.23 | 0.00 | -0.07 | -0.18 | 0.15 | 0.01 | 0.20 | 0.34 | -0.01 | 0.06 | 1.00 | |
| 13 | Central bank instrument independence | -0.19 | -0.08 | 0.01 | -0.07 | -0.12 | 0.04 | -0.14 | -0.13 | 0.27 | -0.15 | -0.25 | 0.05 | 1.00 |

Table B.3. **Panel unit root tests**

| | ADF-Fisher | | PP-Fisher | |
|---|---|---|---|---|
| | Statistic | P-value | Statistic | P-value |
| Inflation | 335.97 | 0.00 | 441.46 | 0.00 |
| Output growth | 326.67 | 0.00 | 343.47 | 0.00 |
| Output volatility | 427.96 | 0.00 | 484.27 | 0.00 |
| Exchange rate volatility | 528.81 | 0.00 | 553.50 | 0.00 |
| Fiscal balance | 278.12 | 0.00 | 284.65 | 0.00 |
| Government debt | 491.17 | 0.00 | 591.97 | 0.00 |
| Trade openness | 348.88 | 0.00 | 370.69 | 0.00 |
| External debt | 272.15 | 0.00 | 291.47 | 0.00 |
| Financial development | 153.49 | 0.01 | 96.18 | 0.94 |
| Economic development | 743.72 | 0.00 | 588.55 | 0.00 |
| Financial openness | 92.19 | 0.36 | 114.38 | 0.06 |

*Notes:* The Table reports Fisher-type panel unit root tests for all explanatory variables, except dummies. We use both ADF and PP (Phillips-Perron) tests. The PP test is robust to serial correlation and heteroscedasticity. The automatic selection of lags is based on the Schwartz criterion. We include individual intercepts to control for level differences between the cross-sections. Probabilities for Fisher tests are computed using an asymptotic chi-square distribution. P-value $< 0.05$ indicates the rejection of the null hypothesis of a common unit root on the 5% significance level and suggests that a particular variable is stationary.

Table C.1. **Country sample**

| Advanced countries (25) | | | | |
|---|---|---|---|---|
| Inflation targeters (12) | | Non-inflation targeters (13) | | |
| Australia | New Zealand | Austria | Italy | |
| Canada | Norway | Belgium | Japan | |
| Finland | Spain | Denmark | Luxemburg | |
| Iceland | Sweden | France | Netherlands | |
| Israel | Switzerland | Germany | Portugal | |
| Korea | United Kingdom | Greece | United States | |
| | | Ireland | | |

| Emerging and developing countries (59) | | | | |
|---|---|---|---|---|
| Inflation targeters (17) | | Non-inflation targeters (42) | | |
| Brazil[#] | Peru[#] | Albania[#] | Egypt | Pakistan |
| Chile | Philippines | Algeria | El Salvador | Panama |
| Colombia | Poland[#] | Angola[#] | Honduras | Paraguay |
| Czech Republic | Romania[#] | Argentina[#] | Hong Kong | Russia[#] |
| Ghana[#] | Slovakia | Armenia[#] | India | Serbia[#] |
| Guatemala | South Africa | Azerbaijan[#] | Iran | Singapore |
| Hungary | Thailand | Belarus[#] | Jordan | Slovenia |
| Indonesia | Turkey[#] | Bolivia | Kazakhstan[#] | Sri Lanka |
| Mexico | | Bulgaria[#] | Latvia[#] | Sudan[#] |
| | | China | Lithuania[#] | Tunisia |
| | | Costa Rica | Malaysia | Ukraine[#] |
| | | Croatia[#] | Mongolia[#] | Uruguay[#] |
| | | Dominican Rep.[#] | Morocco | Vietnam |
| | | Ecuador[#] | Nigeria[#] | Venezuela[#] |

*Note:* [#] Countries with hyperinflation.

Table C.2. **Descriptive statistics, advanced countries, 1985–2011**

| Country group | Variable | Pre-adoption period | Post-adoption period | Difference |
|---|---|---|---|---|
| 'Loose' adoption dates | | | | |
| IT | Average inflation level | 11.59 | 2.75 | −8.84 |
| | Average inflation volatility | 12.63 | 1.74 | −10.90 |
| Non-IT | Average inflation level | 4.80 | 2.13 | −2.97 |
| | Average inflation volatility | 1.65 | 1.12 | −0.53 |
| 'Strict' adoption dates | | | | |
| IT | Average inflation level | 8.85 | 2.52 | −6.33 |
| | Average inflation volatility | 10.78 | 1.47 | −9.31 |
| Non-IT | Average inflation level | 4.40 | 2.05 | −2.35 |
| | Average inflation volatility | 1.76 | 1.07 | −0.69 |

Table C.3. **Descriptive statistics, emerging and developing countries, 1990–2011**

| Country group | Variable | Pre-adoption period | Post-adoption period | Difference |
|---|---|---|---|---|
| 'Loose' adoption dates | | | | |
| IT | Average inflation level | 209.71 | 6.73 | −202.98 |
| | Average inflation volatility | 301.85 | 4.10 | −297.75 |
| Non-IT | Average inflation level | 227.25 | 9.91 | −217.34 |
| | Average inflation volatility | 493.32 | 8.82 | −484.50 |
| 'Strict' adoption dates | | | | |
| IT | Average inflation level | 126.56 | 5.50 | −121.06 |
| | Average inflation volatility | 234.67 | 2.43 | −232.24 |
| Non-IT | Average inflation level | 176.57 | 8.32 | −168.25 |
| | Average inflation volatility | 438.97 | 5.26 | −433.71 |

# Samenvatting*

Dit proefschrift concentreert zich op twee monetaire beleidsstrategiëen, *monetary targeting* en *inflation targeting*. Het proefschrift behandelt de volgende vier onderzoeksvragen:

1. Hebben veranderingen in financiële systemen invloed op de beslissing om afstand te doen van *monetary targeting*?

2. Welke determinanten zijn belangrijk bij het aannemen van *inflation targeting*?

3. Hoe beïnvloeden ruimtelijke interacties tussen landen de beslissing om over te gaan tot *inflation targeting*?

4. Heeft *inflation targeting* effect op inflatie en verschilt het effect tussen landen?

Hoofdstuk 2 beantwoordt de eerste onderzoeksvraag en onderzoekt hoe hervormingen in en eigenschappen van financiële systemen de waarschijnlijkheid beïnvloeden dat landen afstand doen van *monetary targeting*. Hierbij houden we rekening met macroeconomische, fiscale, externe, en institutionele controlevariabelen die samenhangen met de beslissing van landen om deze monetaire strategie te verlaten. Onze bevindingen suggereren dat landen met geliberaliseerde, gedereguleerde, ontwikkelde, en gedollariseerde financiële systemen de strategie van *monetary targeting* eerder achter zich zullen laten. Bovendien beïnvloedt het heersende wisselkoersregime de

* I thank Jan Jacobs for translating the summary.

kans om *monetary targeting* op te geven afhankelijk van het niveau van kapitaalmobiliteit. In overeenstemming met de *policy trilemma* hypothese laten onze resultaten ook zien dat landen met beperkte kapitaalmobiliteit geldgroeidoelen kunnen haneren en tegelijkertijd vaste wisselkoersen kunnen behouden. Echter, bij een hoge kapitaalmobiliteit is een regime van vaste wisselkoersen onverenigbaar met *monetary targeting*. We vinden bovendien dat meer ontwikkelde landen met vrij lage inflatie en hoge begrotingstekorten *monetary targeting* eerder zullen verlaten. De uitkomsten voor opkomende – en ontwikkelingslanden verschillen van die voor ontwikkelde landen. Financiële dollarisatie verhoogt de kans op het verlaten van *monetary targeting* in ontwikkelde landen, terwijl financiële ontwikkeling belangrijk is in opkomende – en ontwikkelingslanden. Financiële liberalisatie speelt een significante rol zowel in ontwikkelde als ontwikkelingslanden.

Hoofdstuk 3 gaat in op de tweede onderzoeksvraag door te onderzoeken welke economisch, fiscale, externe, financiële, en institutionele factoren de waarschijnlijkheid beïnvloeden dat *inflation targeting* wordt aangenomen. De noviteit van onze aanpak is het uitsluiten van de periode na de adoptie in de empirische analyse. De resultaten suggereren dat landen met lage inflatie, hoge productie en wisselkoersvolatiliteit, een systeem van flexibele wisselkoersen en vrij lage overheidsschuld eerder *inflation targeting* zullen aannemen. Landen met minder goed ontwikkelde financïele markten en een op de markt gebaseerd financiëel system zullen deze strategie ook eerder aannemen. De uitkomsten tussen het aannemen van *soft inflation targeting* en *full-fledged inflation targeting* verschillen enigzins. Inflatie is minder belangrijk bij het aannemen van *soft inflation targeting* dan bij *full-fledged inflation targeting*. Om de robustheid te controleren, onderscheiden we twee vormen van *inflation targeting* — *inflation targeting* met meerdere doelen en *inflation targeting* met slechts één doel, inflatie. We vinden dat verschillende verklarende variabelen de kans beïnvloeden verschillende vormen van *inflation targeting* aan te nemen. Bovendien wordt de kans om over te stappen van *inflation targeting* met meerdere doelen naar *inflation targeting* met één doel beïnvloed door lagere inflatie en groei, betere fiscale discipline en flexibele wisselkoersen. Ten slotte, onze gevoeligheidsanalyses laten zien dat factoren die leiden tot het aannemen van *inflation targeting* verschillen tussen landen binnen en buiten de OESO. Deze uitkomst kan worden verklaard uit het bestaan van aanzienlijke verschillen tussen deze groepen van landen in termen van macroeconomische karakteristieken, geloofwaardigheid van hun centrale banken, en doelstellingen van monetair beleid.

Hoofdstuk 4 verschaft aanvullende informatie over de factoren achter het aannemen van *inflation targeting*. We toetsen of karakteristieken van landen de beslissing om *inflation targeting* aan te nemen vóór en na de adoptie anders beïnvloeden. We gebruiken een structurele breukanalyse met een geleidelijke transitiefunctie om de periodes vóór en na de adoptie te onderscheiden. De uitkomsten suggereren dat er een structurele verandering in economische en institutionele karakteristieken optreedt in de periode vóór en na de adoptie. Inflatie speelt de meest prominente rol; het effect van inflatie op de kans dat *inflation targeting* wordt aangenomen wordt zwaar overschat in het model waarin de periode na de adoptie is meegenomen vergeleken met het model zonder deze periode. Oftewel, het opnemen van de periode na adoptie in de empirische analyse van het aannemen van *inflation targeting* leidt tot vertekende uitkomsten. Om deze vertekening eruit te halen, is het noodzakelijk observaties van na de adoptie van *inflation targeting* te negeren, zoals is gedaan in de Hoofdstukken 3 en 5.

Hoofdstuk 5 voegt een ruimtelijke econometrische dimensie toe aan de analyse van *inflation targeting*. We construeren een ruimtelijk probit model met twee ruimtelijk vertraagde variabelen, één voor landen die aan het begin van de periode nog niet zijn overgegaan op *inflation targeting* en één voor landen die de overgang al wel hebben gemaakt. Drie ruimtelijke gewichtenmatrices zijn gebruikt, gebaseerd op de tien naaste buurlanden, gemeenschappelijke taal, en gemeenschappelijke juridische oorsprong. De schattingsuitkomsten zijn gevoelig voor de keuze van de ruimtelijke gewichtenmatrix. Bij de gewichtenmatrix gebaseerd op het hebben van een gemeenschappelijke taal spelen interactie effecten met landen die al zijn overgegaan op *inflation targeting* in de lopende periode geen rol, terwijl landen die al eerder zijn overgegaan een negatieve invloed hebben op andere landen die de strategie willen aannemen. Een mogelijke verklaring voor dit negatieve effect is dat de kans op het overgaan op inflation targeting in de loop van de tijd afneemt omdat het aantal landen dat nog niet is overgegaan kleiner wordt. Voor de ruimtelijke gewichtenmatrix gebaseerd op een gemeenschappelijke juridische oorsprong vinden we dat landen die *inflation targeting* aannemen in de lopende periode de kans dat andere landen deze strategie aannemen in dezelfde periode aanzienlijk verhogen. Gebruiken we de gewichtenmatrix gebaseerd op de tien naaste buurlanden dan zijn beide ruimtelijke variabelen significant. Bovendien vinden we bewijs voor ruimtelijke overloopeffecten van karakteristieken van landen op het aannemen van *inflation targeting*.

Hoofdstuk 6 behandelt de laatste onderzoeksvraag door middel van een uitgebreide analyse van de effecten van *inflation targeting* op inflatie. We onderzoeken de groepen van ontwikkelde landen en opkomende – en ontwikkelingslanden afzonderlijk, gebruikmakend van twee adoptietijdstippen (*'loose'* en *'strict'*) en twee schattingsperioden. Om te achterhalen of uitkomsten afhangen van de keuze van de methodologie passen we twee schattingstechnieken toe — *difference-in-differences* en *propensity score matching*. De schattingsuitkomsten tussen de groepen van landen verschillen aanzienlijk. *Inflation targeting* heeft geen significant effect op inflatie in ontwikkelde landen, terwijl het inflatie significant verlaagd in opkomende – en ontwikkelingslanden. Echter, het uitsluiten van landen met hoge inflatie van de laatste groep versterkt de negatieve invloed van *inflation targeting*. Bovendien zijn de uitkomsten gevoelig voor de keuze van het adoptietijdstip. Ten slotte, beide methodologische benaderingen leiden tot dezelfde conclusies.